SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – I – IRRIGATION ENGINEERING – SCI1401

IRRIGATION PRINCIPLES

Irrigation

Irrigation can be defined as human manipulation of the hydrologic cycle to improve crop production and quality and and to decrease economic efforts of drought.

Irrigation is the artificial application of water to plants for their growth and maturity. Irrigation water is supplied to supplement the water available from rainfall and the contribution of soil moisture from ground water. Necessity of irrigation, advantages and disadvantages of irrigation are described briefly below.

Figure 1: Irrigation

Necessity of Irrigation

1. Rainfall is less than the water requirement of the plants.
2. Rainfall is sufficient, but the spatial distribution of rainfall is not as per requirement.
3. Rainfall is sufficient and the spatial distribution is also good, but the temporal distribution is not as per requirement.
4. Advanced scientific development (HYV-High yield variety).

Advantages and Disadvantages of Irrigation

Some of the advantages of irrigation are as follows.

- Increase of food production.
- Modify soil or climate environment – leaching.
- Lessen risk of catastrophic damage caused by drought.
- Increase income & national cash flow.
- Increase labor employment.
- Increase standard of living.
- Increase value of land.
- National security thus self sufficiency.
- Improve communication and navigation facilities.
- Domestic and industrial water supply.
- Improve ground water storage.
- Generation of hydro-electric power

Disadvantages of Irrigation

The following are the disadvantages of irrigation.

- Water logging.
- Salinity and alkalinity of land
- Ill aeration of soil.
- Pollution of underground water.
- Results in colder and damper climate causing outbreak of diseases like malaria.

Benefits of irrigation

With the introduction of irrigation, there have been many advantages, as compared to the total dependence on rainfall. These may be enumerated as under:

1. **Increase in crop yield:**

   The production of almost all types of crops can be increased by providing the right amount of later at the right time, depending on its shape of growth. Such a controlled supply of water is possible only through irrigation.

2. Protection from famine

The availability of irrigation facilities in any region ensures protection against failure of crops or famine due to drought. In regions without irrigation, farmers have to depend only on rains for growing crops and since the rains may not provide enough rainfall required for crop growing every year, the farmers are always faced with a risk.

3. Cultivation of superior crops

With assured supply of water for irrigation, farmers may think of cultivating superior variety of crops or even other crops which yield high return. Production of these crops in rain-fed areas is not possible because even with the slight unavailability of timely water, these crops would die and all the money invested would be wasted.

4.Elimination of mixed cropping

In rain-fed areas, farmers have a tendency to cultivate more than one type of crop in the same field such that even if one dies without the required amount of water, at least he would get the yield of the other. However, this reduces the overall production of the field. With assured water by irrigation, the farmer would go for only a single variety of crop in one field at anytime, which would increase the yield.

5. Economic development

With assured irrigation, the farmers get higher returns by way of crop production throughout the year. The government in turn, benefits from the tax collected from the farmers in base of the irrigation facilities extended.

6.Hydro power generation:

Usually, in canal system of irrigation, there are drops or differences in elevation of canal bed level at certain places. Although the drop may not be very high, this difference in elevation can be used successfully to generate electricity. Such small hydro electric generation projects, using bulb-turbines have been established in many canals, like Ganga canal, Sarada canal, Yamuna canal etc.

7.Domestic and industrial water supply

Some water from the irrigation canals may be utilized for domestic and industrial water supply for nearby areas. Compared to the irrigation water need, the water requirement for domestic and industrial uses is rather small and does not affect the total flowmuch. For example, the town of Siliguri in the Darjeeling district ofWest Bengal, supplies its residents with the water from Teesta Mahananda link canal.

Development of Irrigation

Archaeological investigation has identified as evidence of irrigation where the natural rainfall was insufficient to support crops for rainfed agriculture.

Perennial irrigation was practiced in the Mesopotamian plain whereby crops were regularly watered throughout the growing season by coaxing water through a matrix of small channels formed in the field.

The earliest mentions of irrigation are found in Rig Veda and various ancient literatures. Later, the 4th-century BCE Indian scholar Patanjali, mentions tapping several rivers for irrigation. Texts from the Maurya Empire era (3rd century BCE) mention that the state raised revenue from charging farmers for irrigation services from rivers.

Patanjali, in Yogasutra of about the 4th century, explains a technique of yoga by comparing it to "the way a farmer diverts a stream from an irrigation canal for irrigation". In Tamil Nadu, the Grand Anicut (canal) across the Kaveri river was implemented in the 3rd century CE, and the basic design is still used today.

Waterworks were undertaken during the Delhi Sultanate and the Mughal Empire era from the 12th to 18th centuries. However, these were primarily to supply water to the palaces and parks of the sultans and other officials.

Colonial era

Ganges irrigation canal built during the colonial era, and inaugurated in 1854.In 1800, some 800,000 hectares was irrigated in India.The British Raj by 1940 built significant number of canals and irrigation systems in Uttar Pradesh, Bihar,Punjab, Assam and Orissa. The Ganges Canal reached 350 miles from Haridwar to Kanpur in Uttar Pradesh. In Assam, a jungle in 1840, by 1900 had 4,000,000 acres under cultivation, especially in tea plantations. In all, the amount of irrigated land multiplied by a factor of eight.

Much of the increase in irrigation during British colonial era was targeted at dedicated poppy and opium farms in India, for exports to China. Major irrigation canals were built after millions of people died each in a series of major famines in the 19th century in British India. In 1900, British India (including Bangladesh and Pakistan) had about 13 million ha under irrigation. By 1947, this had increased to about 22 million ha of irrigation. Arthur Cotton led some irrigation canal projects in the Deccan peninsula, and landmarks are named after him in Andhra Pradesh and Tamil Nadu. However, much of the added irrigation capacity during the colonial era was provided by groundwater wells and tanks, operated manually.

Irrigation trends since 1947

One of the sections of Bhakra Canal system in north India. This canal network irrigates over 4 million hectares of land.

India's irrigation covered crop area was about 22.6 million hectares in 1951, and it increased to a potential of 90 mha at the end of 1995, inclusive of canals and groundwater wells. However, the potential irrigation relies of reliable supply of electricity for water pumps and maintenance, and the net irrigated land has been considerably short. According to 2001/2002 Agriculture census, only 58.1 million hectares of land was actually irrigated in India. The total arable land in India is 160 million hectares (395 million acres). According to the World Bank, only about 35% of total agricultural land in India was reliably irrigated in 2010.

The ultimate sustainable irrigation potential of India has been estimated in a 1991 United Nations' FAO report to be 139.5 million hectares, comprising 58.5 Mha from major and medium river-fed irrigation canal schemes, 15 Mha from minor irrigation canal schemes, and 66 Mha from groundwater well fed irrigation.

India's irrigation is mostly groundwater well based. At 39 million hectares (67% of its total irrigation), India has the world's largest groundwater well equipped irrigation system (China with 19 Mha is second, USA with 17 Mha is third).

India has spent Rs. 16,590 crore on irrigation development between 1950 and 1985. Between 2000-2005 and 2005-2010, India proposed to invest a sum of Rs. 1,03,315 crore and 2,10,326 crore on irrigation and flood control in India.

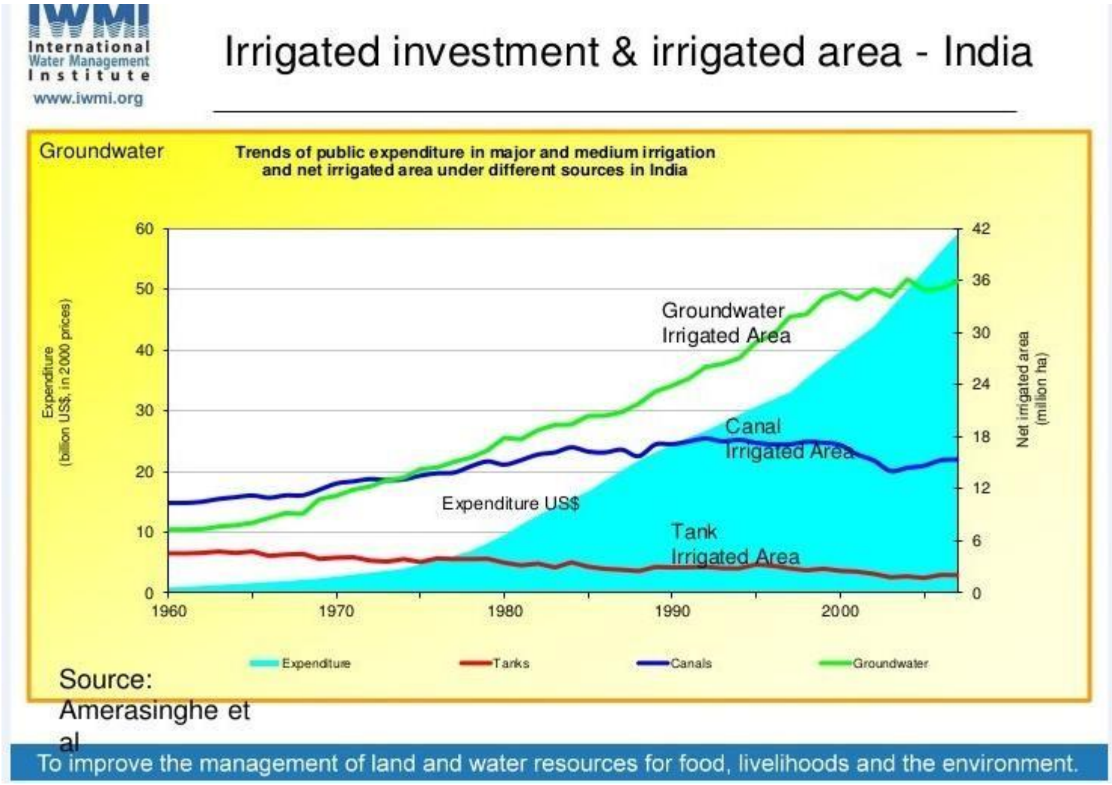


Figure 2: Irrigation Investment

Methods of Field Water Application

Irrigation water conveyed to the head or upstream point of a field must be applied efficiently on the whole area such that the crops growing in the either fields gets water more or less uniformly. Naturally it may be observed that a lot depends on the topography of the land since a large area with uneven topography would result in the water spreading to the low lying areas. The type of crop grown also immensely matter as some like rice, require standing water.

depths at almost all stages of its growth. Some, like potato, on the other hand, suffer under excess water conditions and require only the right amount of water to be applied at the right time. Another important factor determining the way water is to apply in the fields is the quantity of water available at any point of time. If water is scarce, as what is actually happening in many parts of the country, then it is to be applied through carefully controlled methods with minimum amount of wastage. Usually these methods employ pressurized flow through pipes which is either sprinkled over the crop or applied carefully near the plant root. On the other hand when water is rather unlimited during the crop growing season as in deltaic regions, the river flood water is allowed to inundate as much area as possible as long the excess water is available. Another important parameter dictating the choice of the irrigation method is the type of soil. Sometimes water is applied not on the surface of the field but is used to moist the root zone of the plants from beneath the soil surface. Thus, in effective the type of irrigation methods can be broadly divided as under :

Surface irrigation method

- Subsurface irrigation method
- Sprinkler irrigation system
- Drip irrigation system

Each of these methods has been discussed in the subsequent section of this lesson.

Surface Irrigation Methods

In this system of field water application the water is applied directly to the soil from a channel located at the upper reach of the field.

It is essential in these methods to construct designed water distribution systems to provide adequate control of water to the fields and proper land preparation to permit uniform distribution of water over the field. One of the surface irrigation methods is flooding method.

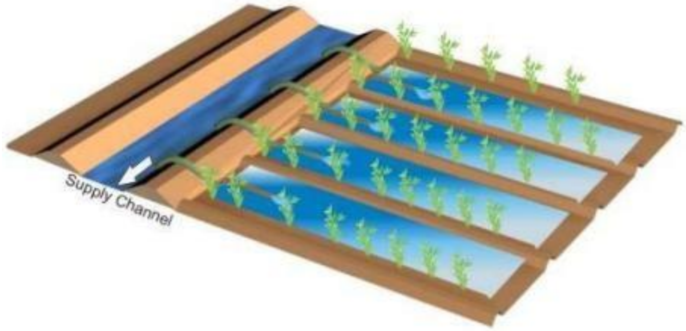
Figure 3: Surface Irrigation

Flooding method

Where the water is allowed to cover the surface of land in a continuous sheet of water with the depth of applied water just sufficient to allow the field to absorb the right amount of water needed to raise the soil moisture up to field capacity,. A properly designed size of irrigation stream aims at proper balance against the intake rate of soil, the total depth of water to be stored in the root zone and the area to be covered giving a reasonably uniform saturation of soil over the entire field. Flooding method has been used in India for generations without any control what so ever and is called uncontrolled flooding. The water is made to enter the fields bordering rivers during folds. When the flood water inundates the flood plane areas, the water distribution is quite uneven, hence not very efficient, as a lot of water is likely to be wasted as well as soils of excessive slopes are prone to erosion. However the adaptation of this method doesn’t cost much. The flooding method applied in a controlled way is used in two types of irrigation methods as under:

Border irrigation method

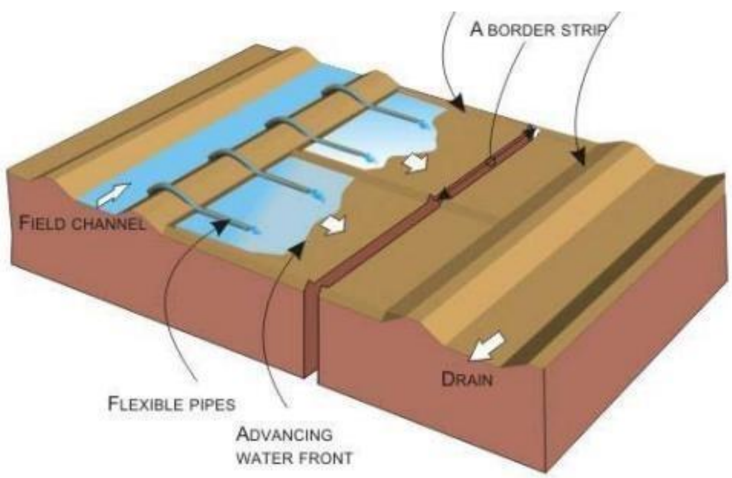
Border irrigation Borders are usually long uniformly graded strips of land separated by earth bunds (low ridges) as shown in Figure



Border irrigation with water being applied to the borders with the help of flexible pipes, acting as siphons

Figure 4: Surface Irrigation

The essential feature of the border irrigation is to provide an even surface over which the water can flow down the slope with a nearly uniform depth. Each strip is irrigated independently by turning in a stream of water at the upper end as shown in the following Figure.



Water entering each border strip independently

Figure 5: Surface Irrigation

The water spreads and flow down the strip in a sheet confined by border ridges. When the advancing water reaches the lower end of the border, the stream is turned off. For uniform advancement of water front the borders must be properly leveled. The border shown in the figures above are called straight borders, in which the border strips are laid along the direction of

general slope of the field. The borders are sometimes laid along the elevation contours of the topography when the land slope is excessive. That method of border is called **contour border method of irrigation**

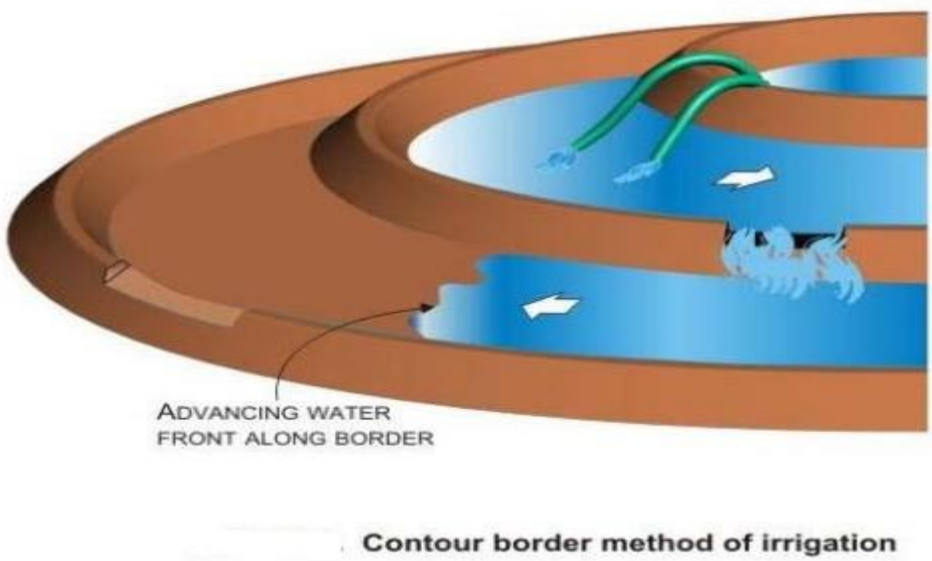


Figure 6: Surface Irrigation

The straight border irrigation is generally suited to the larger mechanized farms as it is designed to produce long uninterrupted field lengths for ease of machine operations. Borders can be 800m or more in length and 3 – 30 m wide depending on variety of factors. It is less suited to small scale farms involving hand labour or animal powered cultivation methods. Generally, border slopes should be uniform, with a minimum slope of 0.05% to provide adequate drainage and a maximum slope of 2% to limit problems of soil erosion. As for the type of soil suitable for border irrigation, deep homogeneous loam or clay soils with medium infiltration rates are preferred. Heavy, clay soils can be difficult to irrigate with border irrigation because of the time needed to infiltrate sufficient water into the soil. Basin irrigation is preferable in such circumstances

Basin Irrigation

Basins are flat areas of land surrounded by low bunds. The bunds prevent the water from flowing to the adjacent fields. The basins are filled to desired depth and the water is retained until it infiltrates into the soil. Water may be maintained for considerable periods of time. Basin method of irrigation can be formally divided into two, viz; the check basin method and the ring basin method. The check basin method is the most common method of irrigation used in India. In this method, the land to be irrigated is divided into small plots or basins surrounded by checks, levees (low bunds); as shown in following Figure.

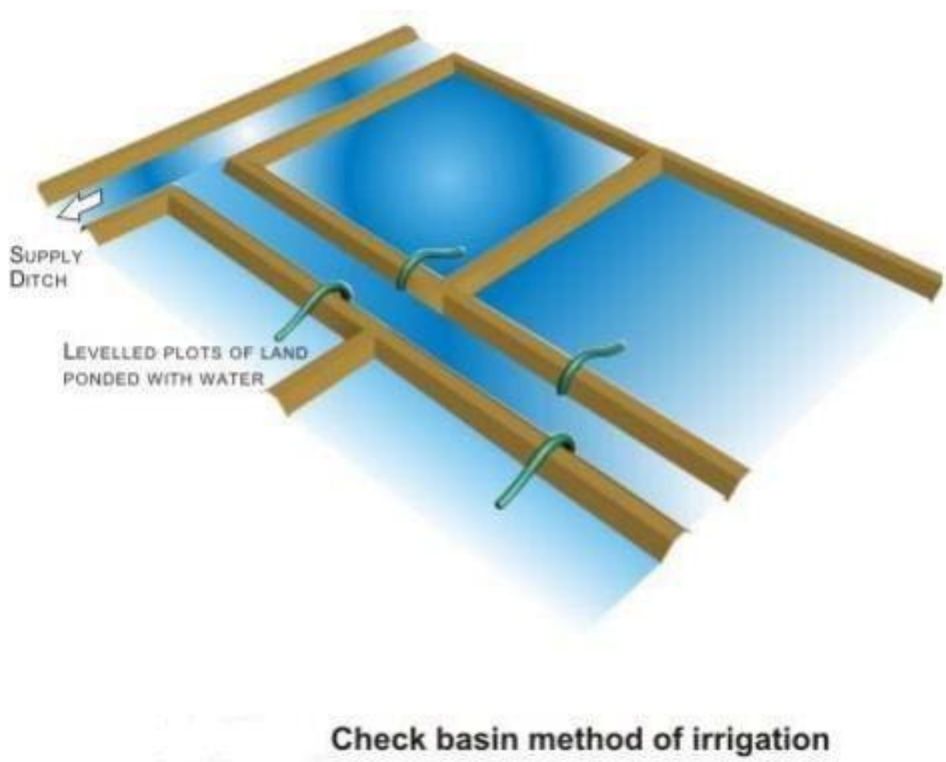


Figure7:SurfaceIrrigation

Each plot or basin has a nearly level surface. The irrigation water is applied by filling the plots with water up to the desired depth without overtopping the levees and the water retained there is allowed to infiltrate into the soil. The levees may be constructed for temporary use or may be semi-permanent for repeated use as for paddy cultivation. The size of the levees depends on the depths of water to be impounded as on the stability of the soil when wet. Water is conveyed to the cluster of check basins by a system of supply channels and lateral field channels or ditches. The supply channel is aligned on the upper side (at a higher elevation) of the field for every two rows of plot as shown in the figure. The size of basins depends not only on the slope but also on the soil type and the available water flow to the basins. Generally, it is found that the following holds good for basin sizes.

Basin size should be small if the

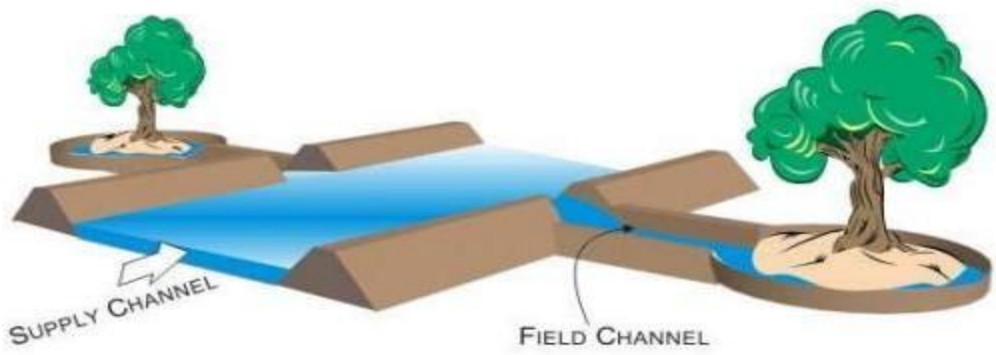
1. Slope of the land is steep.
2. Soil is sandy.
3. Stream size to basin is small.
4. Required depth of irrigation application is small.
5. Field preparation is done by hand or animal traction

Basin size can be large if the

1. Slope of the land is flat
2. Soil is clay.
3. Stream size to the basin is large
4. Required depth of the irrigation is large.
5. Field preparation is mechanized.

Basin irrigation is suitable for many field crops. Paddy rice grows best when its roots are submerged in water and so basin irrigation is the best method for use with the crop.

The other form of basin irrigation is the ring basin method which is used for growing trees in orchards. In this method, generally for each tree, a separate basin is made which is usually circular in shape, as shown in the following Figure.



Ring basin method of irrigation

Figure 8: Surface Irrigation

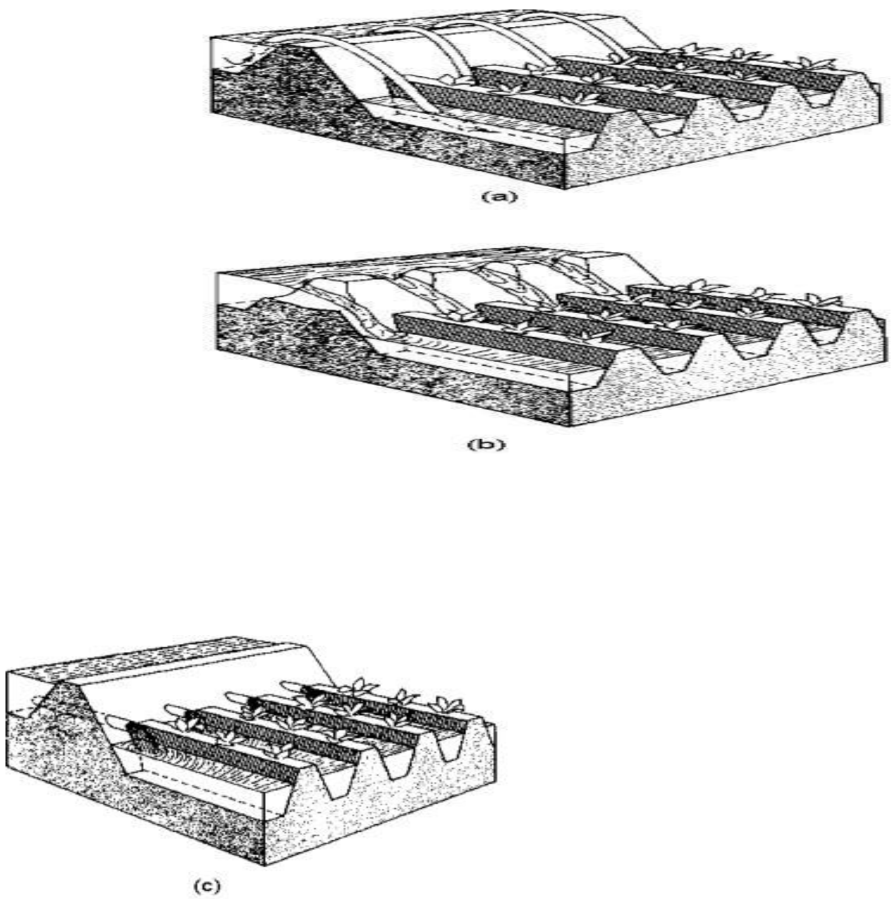
Sometimes, basin sizes are made larger to include two more trees in one basin. Water to the basins is supplied from a supply channel through small field channels conveyed the basins with the supply channel. Trees which can be irrigated successfully using the ring basin method include citrus and banana. Basins can also be constructed on hillside. Here, the ridges of the basins are constructed as in contour border method thus making the only difference between the two is in the application of water. In the border method, the water is applied once during an irrigation cycle and is allowed to flow along the field and as the water infiltrates, till the supply is cutoff. In the basin method, as in a rice field the water is higher at a desired level on the basin. Basin irrigation is suitable for many field crops. Paddy rice grows best when its roots are submerged in water and so basin irrigation is the best method for use with this crop.

Furrow Irrigation

Furrows are small channels, which carry water down the land slope between the crop rows. Water infiltrates into the soil as it moves along the slope. The crop is usually grown on ridges between the furrows, as shown in the following Figure.

It is suitable for all row crops and for crops that cannot stand water for long periods, like 12 to 24 hours, as is generally encountered in the border or basin methods of irrigation.

Water is applied to the furrows by letting in water from the supply channel, either by pipe siphons or by making temporary breaches in the supply channel embankment. The length of time the water is to flow in the furrows depends on the amount of water required to replenish the root zone and the infiltration rate of the soil and the rate of lateral spread of water in the soil.



Furow irrigation method of applying water to a field
(a) Using flexible pipes to siphon out water from field channel
(b) Using the breach method to apply water to the furrows
(c) Pipe outlets to deliver water to the furrows
(Image courtesy: Food and Agriculture Organisation, FAO)

Furrow irrigation is suitable to most soils except sandy soils that have very high infiltration water and provide poor lateral distribution water between furrows.

As compared to the other methods of surface irrigation, the furrow method is advantageous as:

• Water in the furrows contacts only one half to one-fifth of the land surface, thus reducing puddling and clustering of soils and excessive evaporation of water.

• Earlier cultivation is possible Furrows may be straight laid along the land slope, if the slope of the land is small (about 5 percent) for lands with larger slopes, the furrows can be laid along the contours.

Subsurface irrigation methods

As suggested by the name, the application of water to fields in this type of irrigation system is below the ground surface so that it is supplied directly to the root zone of the plants. The main advantages of these types of irrigation is reduction of evaporation losses and less hindrance to cultivation works which takes place on the surface.

There may be two ways by which irrigation water may be applied below ground and these are termed as:

• Natural sub-surface irrigation method

• Artificial sub-surface irrigation method

These methods are discussed further below

Natural Sub-surface irrigation method

Under favorable conditions of topography and soil conditions, the water table may be close enough to the root zone of the field of crops which gets its moisture due to the upward capillary movement of water from the water table. The natural presence of the water table may not be able to supply the requisite water throughout the crop growing season. However, it may be done artificially by constructing deep channels in the field which may be filled with water at all times to ensure the presence of water table at a desired elevation below the root zone depth.

Though this method of irrigation is excellent from both water distribution and labour saving points of view, it is favorable mostly for the following

• The soil in the root zone should be quite permeable

• There should be an impermeable substratum below the water table to prevent deep percolation of water.

• There must be abundant supply of quality water that is one which is salt free, otherwise there are chances of upward movement of these salts along with the moisture likely to lead the conditions of salt incrustation on the surface.

Artificial subsurface irrigation method

The concept of maintaining a suitable water table just below the root zone is obtained by providing perforated pipes laid in a network pattern below the soil surface at a desired depth. This method of irrigation will function only if the soil in the root zone has high horizontal permeability to permit free lateral movement of water and low vertical permeability to prevent deep percolation of water. For uniform distribution of water percolating into the soil, the pipes are required to be very closely spaced, say at about 0.5m. Further, in order to avoid interference with cultivation the pipes have to be buried not less than about 0.4m below the ground surface. This method of irrigation is not very popular because of the high expenses involved, unsuitable distribution of subsurface moisture in many cases, and possibility of clogging of the perforation of the pipes.

Sprinkler Irrigation System

Sprinkler irrigation is a method of applying water which is similar to natural rainfall but spread uniformly over the land surface just when needed and at a rate less than the infiltration rate of the soil so as to avoid surface runoff from irrigation. This is achieved by distributing water through a system of pipes usually by pumping which is then sprayed into the air through sprinklers so that it breaks up into small water drops which fall to the ground. The system of irrigation is suitable for undulating lands, with poor water availability, sandy or shallow soils, or where uniform application of water is desired. No land leveling is required as with the surface irrigation methods. Sprinklers are, however, not suitable for soils which easily form a crust. The

water that is pumped through the pump pipe sprinkler system must be free of suspended sediments. As otherwise there would be chances of blockage of the sprinkler nozzles. A typical sprinkler irrigation system consists of the following components:

1. Pump unit

2. Mainline and sometimes sub mainlines
3. Laterals and Sprinklers

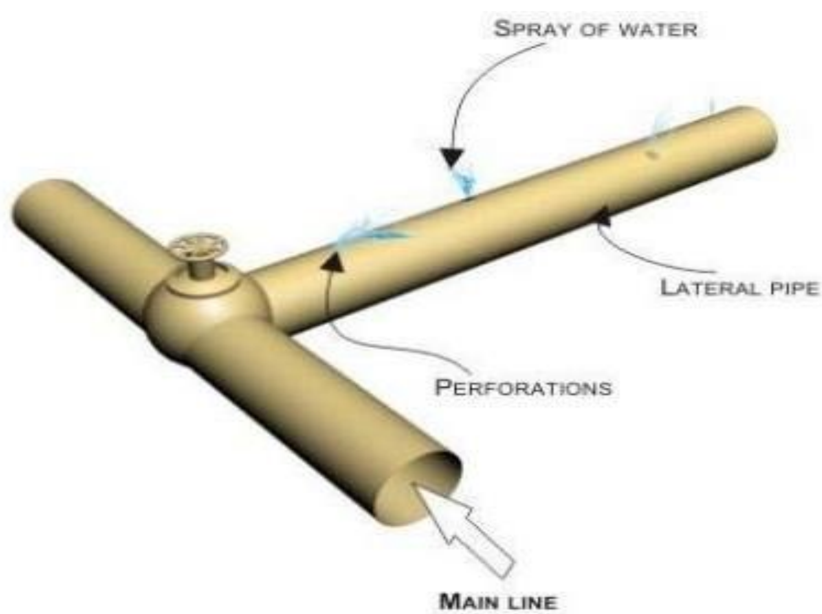
Figure 9: Drip Irrigation

The pump unit is usually a centrifugal pump which takes water from a source and provides adequate pressure for delivery into the pipe system. The mainline and sub mainlines are pipes which deliver water from the pump to the laterals. In some cases, these pipelines are permanent and are laid on the soil surface or buried below ground. In other cases, they are temporary, and can be moved from field to field. The main pipe materials include asbestos cement, plastic or aluminum alloy. The laterals deliver water from the mainlines or sub mainlines to the sprinklers. They can be permanent but more often they are portable and made of aluminium alloy or plastic so that they can be moved easily.

The most common types of sprinklers that are used are:

• Perforated pipe system:

This consists of holes perforated in the lateral irrigation pipes in specially designed pattern to distribute water fairly uniformly. The sprays emanating from the perforations are directed in both sided of the pipe and can cover a strip of land 6 m to 15m wide.



Perforated pipe type of sprinkler system

Figure 10: Drip Irrigation

Rotating head system:

Here small sized nozzles are placed on riser pipes fixed at uniform intervals along the length of the lateral pipe . The lateral pipes are usually laid on the ground surface. The nozzle of the sprinkler rotates due to a small mechanical arrangement which utilizes the thrust of the issuing water. As such, sprinkler irrigation is suited for most rows, field as tree crops and water can be sprayed over or under the crop canopy. However, large sprinklers are not recommended for irrigation of delicate crops such as lettuce because the large water drops produced by the sprinklers may damage the crop. Sprinkler irrigation has high efficiency. It however, varies according to climatic conditions; 60% in warm climate; 70% in moderate climate and 80% in humid or cool climate. Sprinkler irrigation was not widely used in India before the 1980. Although no statistics are available on the total area under sprinkler irrigation, more than 200000 sprinkler sets were sold between 1985 and 1996(with 65000 for 1995-96) according to the National Committee on the use of plastics in agriculture. The average growth rate of sprinkler irrigated area in India is about 25 percent. The cost of installation of sprinkler irrigation depends on a number of factors such as type of crop, the distance from water source.

Drip Irrigation System

Drip Irrigation system is sometimes called trickle irrigation and involves dripping water onto the soil at very low rates (2-20 litres per hour) from a system of small diameter plastic pipes filled with outlets called emitters or drippers. Water is applied close to the plants so that only part of the soil in which the roots grow is wetted, unlike surface and sprinkler irrigation, which involves wetting the whole soil profile. With drip irrigation water, applications are more frequent than with other methods and this provides a very favourable high moisture level in the soil in which plants can flourish. Figure shows a typical layout of the drip irrigation system.

A typical drip irrigation system consists of the following components:

- Pump unit
- Control Head
- Main and sub main lines
- Laterals
- Emitters and drippers

The drip irrigation system is particularly suited to areas where water quality is marginal, land is steeply sloping or undulating and of poor quality, where wateror labour are expensive, or where high value crops require frequent water applications. It is more economical for orchard crops than for other crops and vegetables since in the orchards plants as well as rows are widely spaced. Drip irrigation limits the water supplied for consumptive use of plants. By maintaining a minimum soil moisture in the root zone, thereby maximizing the water saving. A unique feature of drip irrigation is its excellent adaptability to saline water. Since the frequency of irrigation is quite high, the plant base always remains wet which keeps the salt concentration in the plant zone below the critical. Irrigation efficiency of a drip irrigation system is more than 90 percent. Drip irrigation usage in India is expanding rapidly. There is even some Government subsidy to encourage its use.

From about 1000 hectare in 1985, the area under drip irrigation increased to 70860 hectare in 1991, with the maximum developments taking place in the following states:

- Maharashtra (32924 hectare)
- Andhra Pradesh (11585 hectare)

• Karnataka (11412 hectare) The drip irrigated crops are mainly used to irrigate orchards of which the following crops are important ones (according to a 1991 survey):

• Grapes (12000 hectare) • Bananas (6500 hectare)

• Pomegranates (5440 hectare)

• Mangoes

Drip irrigation was also used to irrigate sugarcane (3900 hectare) and coconut (2600 hectare).

SOIL WATER COMPONENTS

Soil is a heterogeneous mass consisting of a three phase system of solid, liquid and gas. Mineral matter, consisting of sand, silt and clay and organic matter form the largest fraction of soil and serves as a framework (matrix) with numerous pores of various proportions.Soil serves as a storage reservoir for nutrients and water needed for plant growth.Soil is a complex mass of mineral and organic particles. The important properties (physical and chemical) that classify soil according to its relevance to making crop production are:

- Soil texture
- Soil structure
- Depth of Soil

Irrigation is the application of water to ensure sufficient soil moisture is available for good plant growth throughout the growing season. Irrigation, as practiced in North Dakota, is called "supplemental irrigation" because it augments the rainfall that occurs prior to and during the growing season.

Irrigation often is used on full-season agronomic or high-value specialty crops to provide a dependable yield every year. It also is used on crops such as potatoes, flowers, vegetables and fruits where water stress affects the quality of the yield.

Most years, some places in the state receive sufficient rainfall for good plant growth. But in many of those years, other areas of the state experience reduced yields and/or reduced quality on nonirrigated crops due to water stress from insufficient soil moisture.

For irrigation planning purposes, the average precipitation during the growing season is not a good yardstick to determine a need for irrigation. The timing and amounts of rainfall during the season, the soil's ability to hold water and the crop's water requirements are all factors that influence the need for irrigation. Any location in the state can have what might be considered "wet or dry" weeks, months and even years.

Under irrigation, soil and water compatibility is very important. If they are not compatible, the applied irrigation water could have an adverse effect on the chemical and physical properties of the soil. Determining the suitability of land for irrigation requires a thorough evaluation of the soil properties, the topography of the land in the field and the quality of water to be used for irrigation. A basic understanding of soil/water/plant interactions will help irrigators efficiently manage their crops, soils irrigation systems and water supplies.

Soil Properties

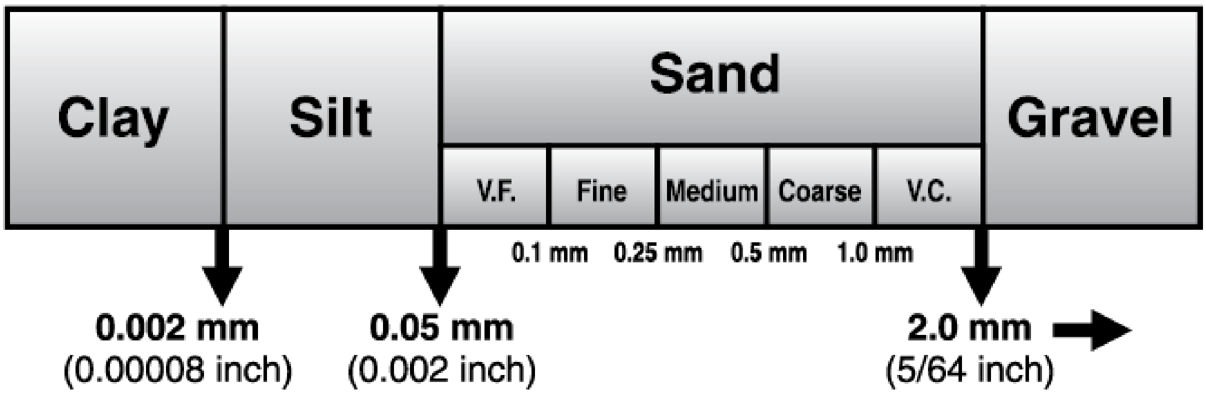
The county soil survey contains detailed soils information for any parcel of land in North Dakota. Soil surveys of every county in North Dakota have been completed by the Natural Resources Conservation Service (NRCS). The official and most current of soil survey information is accessible on the NRCS's Websoil Survey website.

Published copies can be found at local NRCS and NDSU Extension offices, but they may not have the latest soil survey information. The soil survey database provides information on important soil properties such as texture, structure, depth, permeability and chemistry, all of which are important for irrigation management.

Soil Texture

Soil texture is determined by the size and type of solid particles that make up the soil. Soil particles may be mineral or organic. Most irrigated soils in North Dakota are mineral soils.

For mineral soils, the texture classification is based on the relative proportion of the particles less than 2 millimeters (mm) or 5/64th of an inch in size. As shown in Figure 1, the largest particles are sand, the smallest are clay, and silt is in between. The soil texture is based on the percentage of sand, silt and clay (Figure 2).



Classification of soil particles Figure 1

Figure 1. Classification by size of the primary soil particles that define a textural group based on the U.S. Department of Agriculture soil classification system. Under SAND, V.F. refers to very fine and V.C. to very coarse.

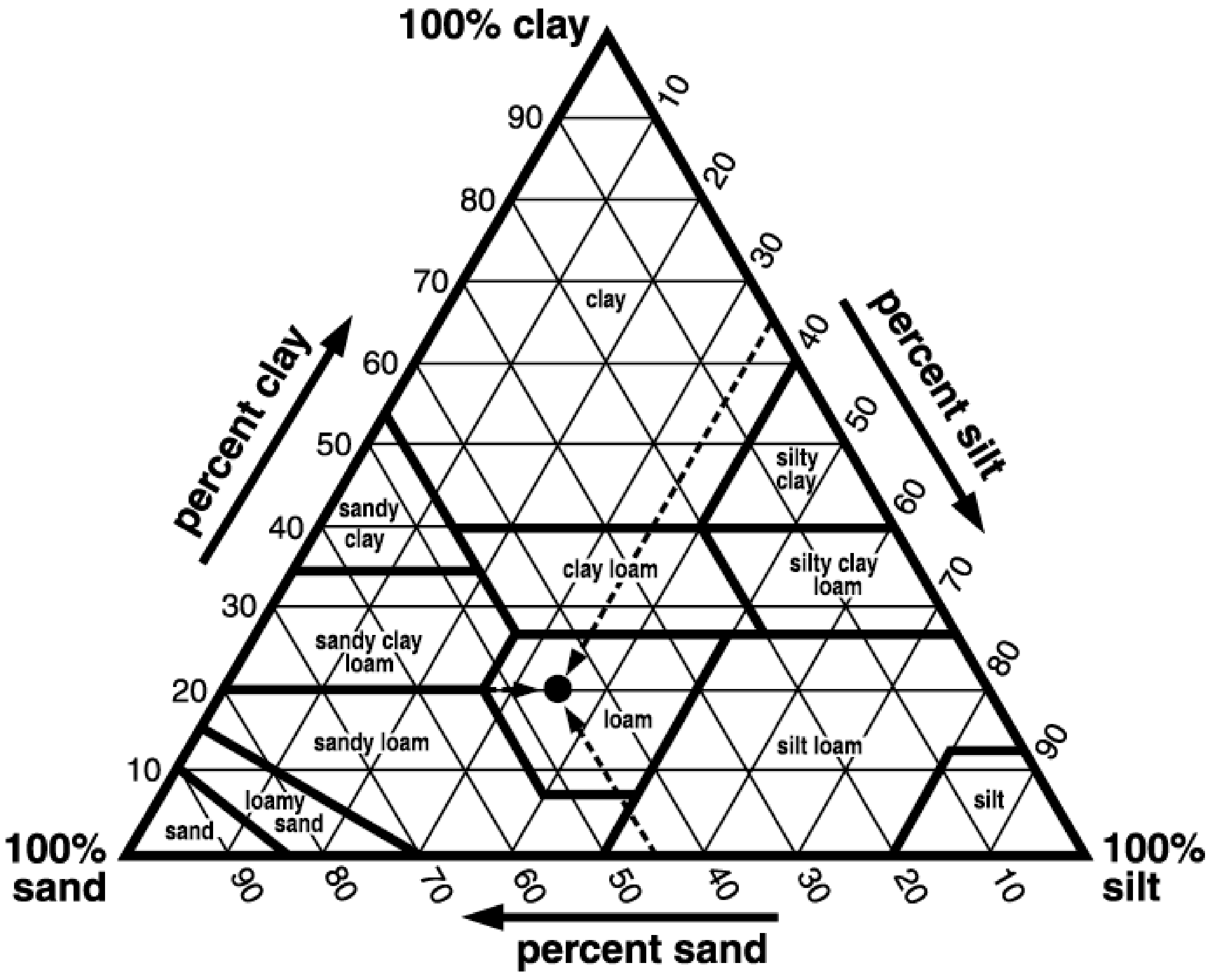


Figure 11: Soil textural triangle

Figure 2. U.S. Department of Agriculture (USDA) soil textural triangle. The percent (by weight) of the sand, silt and clay fraction determines the texture of the soil. The dotted line depicts a loam soil that has 45 percent sand, 35 percent silt and 20 percent clay content.

Soil texture classes may be modified if greater than 15 percent of the particles are organic (for example, mucky silt loam). Soil particles greater than 2 mm are not used to determine soil texture. However, when they make up greater than 15 percent of the soil volume, the textural class is modified (for example, gravelly sand).

Separating and weighing the amount of sand, silt and clay in a sample determines the texture of a mineral soil. For example, if a 100-pound sample of soil were sifted through screens and found to contain 45 pounds of sand, 35 pounds of silt and 20 pounds of clay, then the soil would be composed of 45 percent sand, 35 percent silt and 20 percent clay. As shown by the dotted lines in Figure 2, this soil has a loam texture.

Twelve basic soil textures are shown on Figure 2. Sand, loamy sands and sandy loams are the most common soil textures irrigated in North Dakota.

Soil Structure

Soil structure refers to the grouping of particles of sand, silt and clay into larger aggregates of various sizes and shapes. The processes of root penetration, wetting and drying cycles, freezing and thawing, and animal activity, combined with inorganic and organic cementing agents, produce soil structure (Figure 3). Structural aggregates that are resistant to physical stress are important to the maintenance of soil tilth and productivity. Excessive cultivation or tillage of wet soils disrupt aggregates and accelerate the loss of organic matter, thus causing decreased aggregate stability.

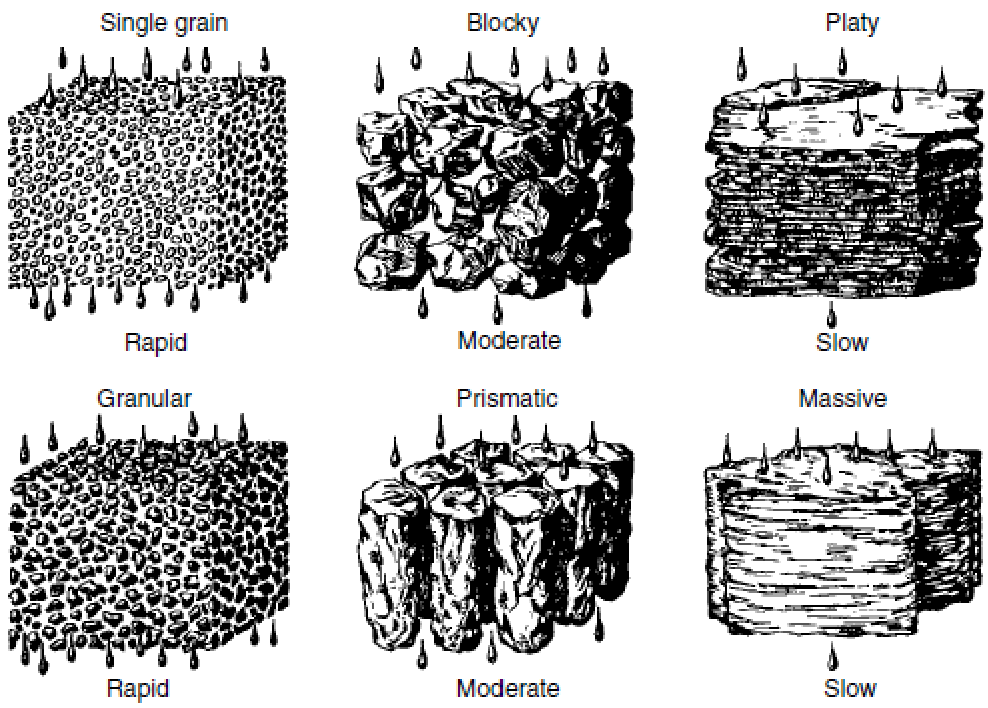


Figure 12. Examples of the most common soil structures. Also shown is the structures'

effect on downward movement (infiltration) of water. (Courtesy of the NRCS, Section 15 of the National Engineering Handbook)

The movement of air, water and plant roots through a soil is affected by soil structure. Stable aggregates result in a network of soil pores that allow rapid exchange of air and water with plant roots. Plant growth depends on rapid rates of exchange.

Practicing beneficial soil management techniques such as using cover crops, reduced tillage, crop rotations, organic matter additions and timely tillage practices can maintain good soil structure. In sandy soils, aggregate stability is often difficult to maintain due to low organic matter, clay content and resistance of sand particles to aggregation processes.

Soil Series

Soil is the layer of the Earth's surface that has been changed by physical or biological processes. The five soil-forming factors that control the process of change are parent material, climate, topography, biota (plants and animals) and time.

Soils are grouped into categories according to their observed properties. The U.S. Department of Agriculture’s classification system consists of six categories. The highest category (soil order) contains 11 basic soil groups, each with a very broad range of properties. The lowest category (soil series) contains more than 12,000 soils, each defining a very narrow range of soil properties.

North Dakota has 339 named soil series. A soil series is unique due to a combination of properties such as texture, structure, topographic position (on the side of a hill or in a valley) or depth to the water table.

A particular soil series describes areas in which these soil conditions are similar. These locations may be in the same field, section, county, state or even region. Soil delineations on county soil survey maps are based on the soil series.

A soil series generally is named after a town near the site that represents the typical properties for that soil. For example, the site with typical properties for the Embden soil series is near Embden, N.D.

Many soil series do not have a deep, uniform soil profile. Restrictive subsurface layers often interfere with root penetration. In these soils, plant roots will be concentrated in the upper part of the soil profile. For example, in the Renshaw loam profile (Figure 4), the majority of the plant roots will be in the top 18 inches because the gravel below is a poor rooting environment. This type of information is important for irrigation management.

Soil Depth

Soil depth refers to the thickness of the soil materials that provide structural support, nutrients and water for plants. In North Dakota, soil series that have bedrock 10 to 20 inches below the surface are described as shallow. Bedrock from 20 to 40 inches is described as moderately deep.

Most soil series in North Dakota have bedrock at depths greater than 40 inches and are described as deep. Depth to contrasting textures is given in the soil series descriptions of the soil survey reports.

The depth to a contrasting soil layer of sand and gravel (Figure 4) can affect irrigation management decisions. If the depth to this layer is less than 3 feet, the rooting depth and available soil water for plants is decreased. Soils with less available water for plants require more frequent irrigations.

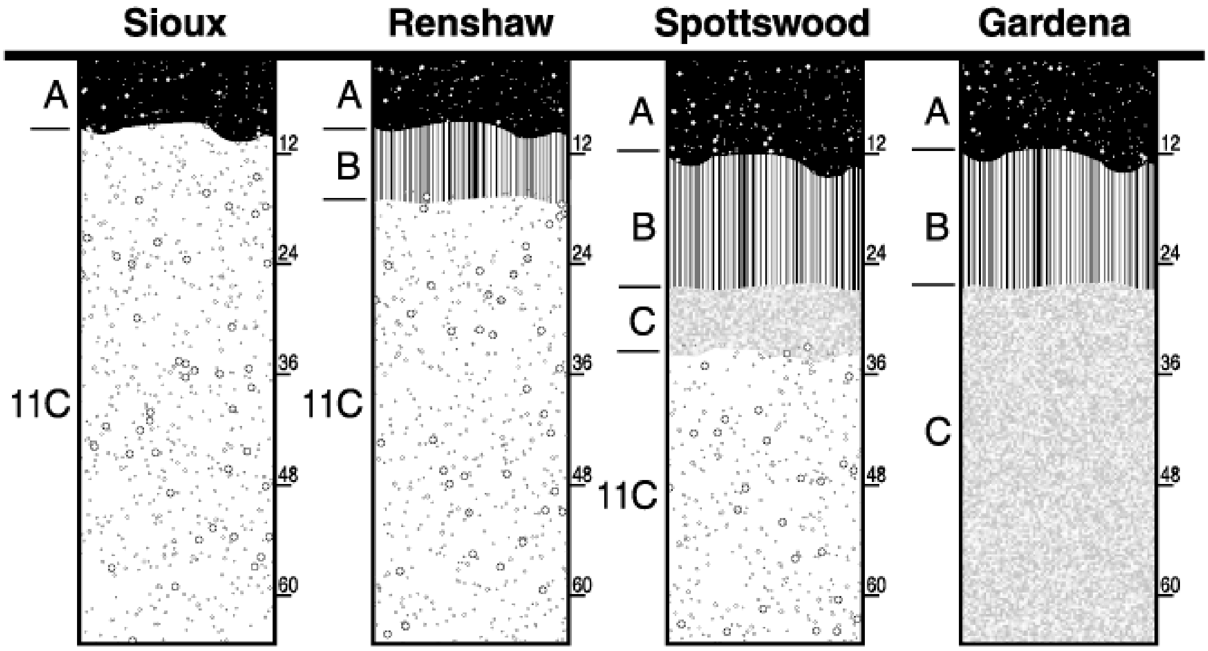


Figure 13.

Soil horizon depths for four representative North Dakota soil series. A, B and C refer to the different soil horizons and IIC indicates a different parent material (for these soil series, it is sand and gravel).

Soil Permeability and Infiltration

A measure of the ability of air and water to move through soil is its permeability. It is influenced by the size, shape and continuity of the pore spaces, which in turn are dependent on the soil bulk density, structure and texture.

Most soil series are assigned to a single permeability class based on the most restrictive layer in the upper 5 feet of the soil profile (Table 1). However, soil series with contrasting textures in the soil profile are assigned to more than one permeability class. In most cases, soils with a slow, very slow, rapid or very rapid permeability classification are considered poor for irrigation.

Table 1. Soil permeability classes.

Classification	Infiltration Rate (inches/hour)
Very slow	less than 0.06
Slow	0.06 to 0.2
Moderately slow	0.2 to 0.6
Moderate	0.6 to 2.0
Moderately rapid	2.0 to 6.0
Rapid	6.0 to 20.0
Very rapid	greater than 20.0

Infiltration is the downward flow of water from the surface through the soil. The infiltration rate (sometimes called intake rate) of a soil is a measure of its ability to absorb an amount of rain or irrigation water during a given time period. It commonly is expressed in inches per hour. It is dependent on the permeability of the surface soil, moisture content of the soil and surface conditions such as roughness (tillage and plant residue), slope and plant cover.

Coarse-textured soils, such as sands and gravel, usually have high infiltration rates. The infiltration rate of medium- and fine-textured soils, such as loams, silts and clays, is lower than coarse-textured soils and is influenced by the stability of the soil aggregates.

Water and plant nutrient losses may be greater on coarse-textured soils. Thus, the timing and quantity of chemical and irrigation water applications is particularly critical on these soils.

Saline and Sodic Soils

Salt-affected soils are grouped according to their content of soluble salts and sodium (Table 2). Saline and sodic soils usually occur in areas where ground water moves upward from a shallow water table close to the soil surface. The water carries dissolved minerals (salts) that accumulate in the soil as the water is evaporated from the soil surface or transpired through the plants to the atmosphere. In general, these soils are not recommended for irrigation.

Table 2. Soil chemistry measurements used to classify saline, sodic and saline-sodic soils.

	Electrical Conductivity* (mmhos/cm)	pH	Sodium Adsorption Ratio* (SAR)
Saline soil	greater than 4	less than 8.5	less than 13
Sodic soil	less than 4	8.5 to 10	greater than 13
Saline-sodic soil	greater than 4	less than 8.5	greater than 13

*Measured from a saturated soil extract

Saline and sodic soils may be of natural or man-made origins. One of the man-made processes is related to irrigation. Under certain combinations of irrigation water quality and soils, salts and/or sodium may accumulate in the root zone and have an adverse effect on plant growth.

Under some conditions, sodium can be controlled in the upper part of the soil through the use of soluble calcium amendments. The replacement of sodium by calcium improves the structure of the soil. Calcium soil amendments can be helpful in situations where land with a majority of unaffected irrigable soils contains pockets (inclusions) of sodium-affected soils. Under irrigation, calcium soil amendments will help where surface crusting has become a problem. Special irrigation management practices may be required on these soils.

Leaching or controlling the water table elevation can manage salt concentrations. Leaching is accomplished by applying more water than the soil will hold in the root zone. Large rainfall events, applying additional irrigation water or both will carry some of the salts below the root zone.

Planting a deep-rooted crop, such as alfalfa, or installing subsurface drainage can accomplish water table control. Deep ditches and tiling are methods of subsurface drainage that have been used successfully in many parts of the world to control the level of the water table.

Soil salt and sodium contents need to be measured to determine precisely the severity of the problem. The salt content of the soil is estimated from an electrical conductivity measurement using one of the following: a soil water extract, soil water slurry or soil paste. The sodium content of the soil often is measured on a soil water extract and expressed as the ratio between the sodium and calcium plus magnesium; it is given the term sodium adsorption ratio (SAR).

Soil sampling the surface layer (top 6 inches) on a periodic basis (every three to five years) will track the change in accumulated salt or sodium. The SAR of the soil samples will indicate if a buildup of sodium has occurred.

Generally, soils with an SAR of 13 from the saturated extract will exhibit significant physical problems due to dispersal of clay particles. Usually a soil with an SAR of 6 or lower from the saturated extract will not have physical problems associated with dispersed clay. However, if periodic sampling indicates that the SAR is increasing, say from 6 to 9, then you may need to consider corrective action.

Topography of the Field

Topography, or the "lay of the land," has a large impact on whether a field can be irrigated. Relief is a component of topography that refers to the difference in height between the hills and depressions in the field. The topographic relief will affect the type of irrigation system to be used, the water conveyance system (ditches or pipes), drainage requirements and water erosion control practices.

The shape and arrangement of topographic landforms and the type of surface waterway network also will influence irrigation management. For example, a low spot in the field where water typically accumulates after a rain may become a place that is continually wet with the addition of irrigation water.

With some crops, such as potatoes, a wet low spot could become a source of disease. For a center pivot, a tower that travels through the low spot could become stuck.

■ **Slope**

Slope is important to soil formation and management because of its influence on runoff, soil drainage, erosion, the use of machinery and choice of crops. Slope is the incline or gradient of a surface and commonly is expressed in percents.

The percent of slope is determined by measuring the difference in vertical elevation in feet over 100 feet of horizontal distance. For example, a 5 percent slope rises or falls 5 feet per 100 feet of horizontal distance.

The shape of the slope is another important characteristic. A convex slope curves outward like the outside surface of a ball, a concave slope curves inward like the inside surface of a saucer, and a plane slope is like a tilted flat surface.

Slopes are described as simple or complex. Simple slopes have a smooth appearance, with surfaces extending in one or perhaps two directions. For example, slopes on alluvial fans and foot slopes of river valleys are regarded as simple. Complex areas have short slopes that extend in several directions and consist of convex and concave slopes much like the knoll and pothole topography found on glacial till plains.

Gravity (surface) irrigation can be used only on simple slopes of 2 percent or less. In general, simple and complex slopes greater than 1 percent should be irrigated only with sprinkler or drip systems. Center pivot sprinkler irrigation systems can operate on slopes up to 15 percent, but generally simple slopes greater than 9 percent are not recommended.

To accommodate gravity or sprinkler irrigation systems, land smoothing can be used to modify the slope in a field. However, land smoothing may cause yield reductions for one to three growing seasons. The places where topsoil was removed are most likely to have yield reductions. Special management using increased organic matter may be required to accelerate soil building in these areas.

Irrigation Water Quality

The quality of some water sources is not suitable for irrigating crops. Irrigation water must be compatible with the crops and soils to which it will be applied. The Soil and Water Testing Laboratory in the Soil Science Department at NDSU provides soil and water compatibility recommendations for irrigation. A water analysis and legal description of the land proposed for irrigation are required before a recommendation can be made.

The quality of water for irrigation purposes is determined by its total dissolved salt content. An analysis of water for irrigation should include the cations (calcium, magnesium and sodium) and the anions (bicarbonate, carbonate, sulfate and chloride). Because some crops are sensitive to boron, it often is included in the analysis.

Irrigation Water Classification

The two most important factors to look for in an irrigation water quality analysis are the total dissolved solids (TDS) and the sodium adsorption ratio (SAR). The TDS of a water sample is a measure of the concentration of soluble salts in a water sample and commonly is referred to as the salinity of the water.

The electrical conductivity (EC) of a water sample often is used as a proxy for TDS. EC can be expressed in many different units, and this often causes confusion. On an irrigation water test report, you might see one of the following units::

Millimhos per centimeter (mmhos/cm)

micromhos per centimeter (µmhos/cm)

deci-Siemens per meter (dS/m)

micro-Siemens per centimeter (µS/cm)

where:

1,000 µmhos/cm = 1 mmho/cm = 1 dS/m = 1,000 µS/cm

The SAR of a water sample is the proportion of sodium relative to calcium and magnesium. Because it is a ratio, the SAR has no units.

Laboratories that perform irrigation water analysis may provide a suitability classification based on a system developed at the U.S. Salinity Laboratory in California (Figure 5). This classification system combines salinity and sodicity. For example, a water sample classified as C3-S2 would have a high salinity rating and a medium SAR rating.

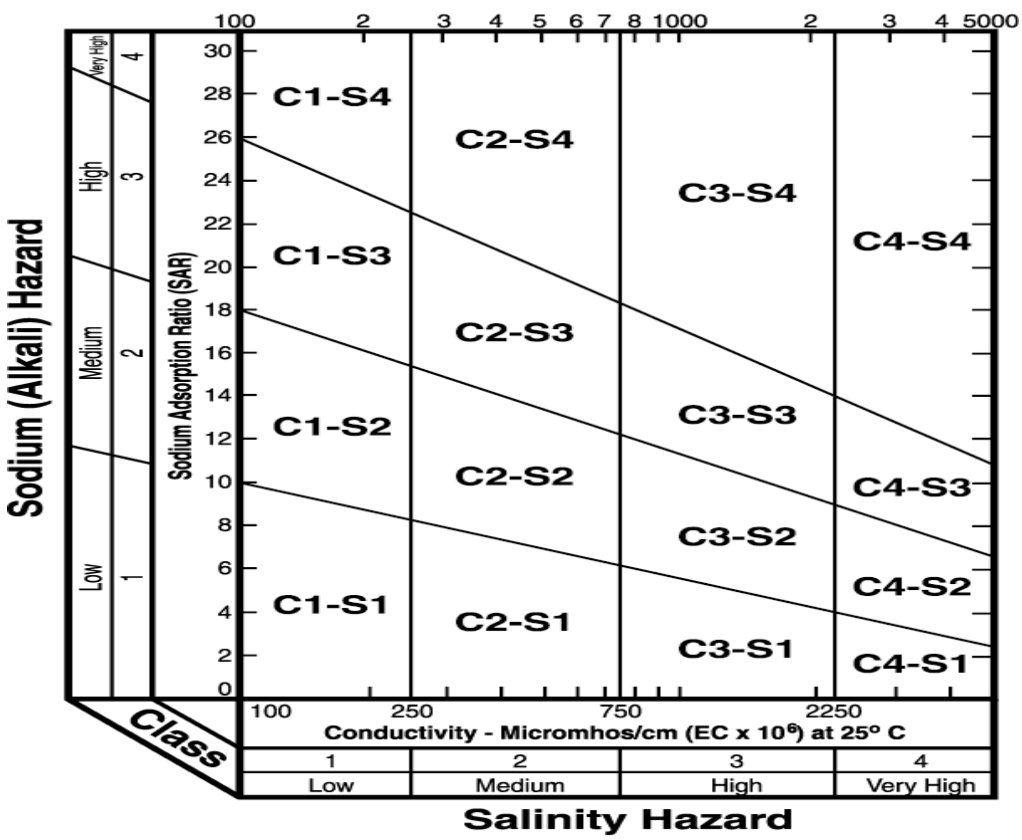


Figure 14 Classification of irrigation water.

Figure 5. Diagram showing the classification of irrigation water.The scale for sodicity is not constant because it depends on the level of salinity. For example, an SAR of 8 is in the S1 category if the salinity is from 100 to 300 µmhos/cm; S2 if the salinity is from 300 to 3,000 µmhos/cm and S3 if the salinity is greater than 3,000 µmhos/cm.

Much of the water in North Dakota is classified in the C2 to C3 salinity range and the S1 to S2 sodium hazard range. In general, any water with an EC greater than 2,000 or an SAR value greater than 6 is not recommended for continuous irrigation in North Dakota.

In cases where sporadic irrigation is practiced (a particular piece of land is irrigated one year out of three or more), lower-quality water may be used. However, the lower-quality water should not have an EC that exceeds 3,000 µmhos/cm or an SAR greater than 10.

Calcium added to irrigation water can lower the SAR and reduce the harmful effects of sodium. The effectiveness of added calcium depends on its solubility in the irrigation water. Calcium solubility is controlled by the source of the calcium (for example, calcium carbonate, gypsum, calcium chloride) and the concentration of other ions in the irrigation water.

Compared with calcium carbonate and gypsum, calcium chloride additions will result in higher concentrations of soluble calcium and be the most effective at lowering irrigation water SAR. However, calcium chloride is considerably more expensive than calcium carbonate and calcium sulfate (gypsum).

■ **Salinity**

C1 - Low-salinity water: Can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of slow and very slow permeability.

C2 - Medium-salinity water: Can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

C3 - High-salinity water: Cannot be used on soils with moderately slow to very slow permeability. Even with adequate permeability, special management for salinity control may be required and plants with good salt tolerance should be selected.

C4 - Very high salinity water: Is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances. The soils must have rapid permeability, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

■ **Sodium**

S1 - Low-sodium water: Can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium.

S2 - Medium-sodium water: Will present an appreciable sodium hazard in fine-textured soils, especially under low leaching conditions. This water may be used on coarse-textured soils with moderately rapid to very rapid permeability.

S3 - High-sodium water: Will produce harmful levels of exchangeable sodium in most soils and requires special soil management, good drainage, high leaching and high organic matter additions.

S4 - Very high sodium water: Generally is unsatisfactory for irrigation purposes except at low and perhaps medium salinity.

Carbonates

Carbonate and bicarbonate ions in the water combine with calcium and magnesium to form compounds that precipitate out of solution. The removal of calcium and magnesium increases the sodium hazard to the soil due to the irrigation water. The increased sodium hazard often is expressed as "adjusted SAR." The increase of "adjusted SAR" from the SAR is a relative indication of the increase in sodium hazard due to the presence of these ions.

Nozzles of sprinkler systems have been plugged by carbonate minerals in some states but this has not been observed in North Dakota. However, carbonate minerals have plugged the emitters in drip irrigation systems in North Dakota. To control this problem, add a mild acid to lower the pH of the irrigation water.

Boron

Boron is essential for the normal growth of all plants, and the quantity required is low compared with other minerals. However, some plants are sensitive to even low boron concentrations. Dry beans are very sensitive to small amounts of boron, but corn, potatoes and alfalfa are more tolerant. In fact, the concentration of boron that will injure the sensitive plants often is close to that required for normal growth of tolerant plants.

Although no problems with boron in water used for irrigation in North Dakota have been documented, testing for this element in irrigation water is a precautionary practice. Boron does occur in some North Dakota ground water at concentrations that are theoretically toxic to some crops.

A boron concentration greater than 2 parts per million (ppm) may be a problem for certain sensitive crops, especially in years that require large quantities of irrigation water.

The Interaction Between Soil and Water

Soil is a medium that stores and moves water. If a cubic foot of a typical silt loam topsoil were separated into its component parts, about 45 percent of the volume would be mineral matter (soil particles), organic residue would occupy about 5 percent of the volume and the rest would be pore space.

The pore space is the voids between soil particles and is occupied by air or water. The quantity and size of the pore spaces are determined by the soil's texture, bulk density and structure.

Water is held in soil in two ways: as a thin coating on the outside of soil particles and in the pore spaces. Soil water in the pore spaces can be divided into two different forms: gravitational water and capillary water (Figure 6).

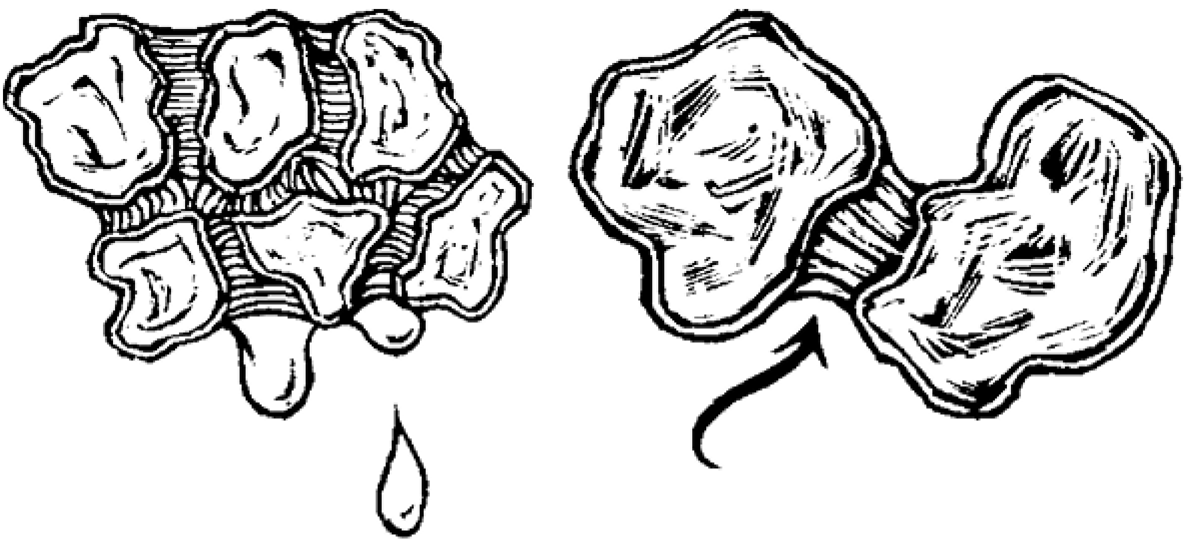


Figure 15: Gravitational water. The pore spaces are Capillary water is held in the pore space against the force

filled with water in excess of their capillary capacity, of gravity.

and the excess, or gravitational water, drains downward.

Figure 6. The two primary ways that water is held in the soil for plants to use are capillary and gravitational forces.

Gravitational water generally moves quickly downward in the soil due to the force of gravity. Capillary water is the most important for crop production because it is held by soil particles against the force of gravity.

A water infiltrates into a soil, the pore spaces fill with water. As the pores are filled, water moves through the soil by gravity and capillary forces. Water movement continues downward until a balance is reached between the capillary forces and the force of gravity.

Water is pulled around soil particles and through small pore spaces in any direction by capillary forces. When capillary forces move water from a shallow water table upward, salts may precipitate and concentrate in the soil as water is removed by plants and evaporation..

Water Holding Capacity of Soils

The four important levels of soil moisture content reflect the availability of water in the soil. These levels commonly are referred to as 1) saturation, 2) field capacity, 3) wilting point and 4) oven dry.

When a soil is saturated, the soil pores are filled with water and nearly all of the air in the soil has been displaced by water. The water held in the soil between saturation and field capacity is gravitational water. Frequently, gravitational water will take a few days to drain through the soil profile and, thus, some can be absorbed by roots of plants.

Field capacity is defined as the level of soil moisture left in the soil after drainage of the gravitational water (Figure 7). Water held between field capacity and the wilting point is available for plant use.

The wilting point is defined as the soil moisture content at which most plants cannot exert enough force to remove water from small pores in the soil. Most crops will be damaged permanently if the soil moisture content is allowed to reach the wilting point. In many cases, yield reductions may occur long before this point is reached.

Capillary water held in the soil beyond the wilting point can be removed only by evaporation. When dried in an oven, nearly all water is removed from the soil. "Oven dry" moisture content is used to provide a reference for measuring the other three soil moisture contents.

When discussing the water-holding capacity associated with a particular soil series, the water available for plant use in the root zone commonly is given (Table 3). Available soil water content commonly is expressed as inches per foot of soil.

Table 3. Available soil moisture holding capacity for various soil textures.

	Available Soil Moisture	
Soil Texture	**inches/inch**	**inches/foot**
Coarse sand and gravel	0.02 to 0.06	0.2 to 0.7
Sands	0.04 to 0.09	0.5 to 1.1
Loamy sands	0.06 to 0.12	0.7 to 1.4
Sandy loams	0.11 to 0.15	1.3 to 1.8
Fine sandy loams	0.14 to 0.18	1.7 to 2.2
Loams and silt loams	0.17 to 0.23	2.0 to 2.8
Clay loams and silty clay loams	0.14 to 0.21	1.7 to 2.5
Silty clays and clays	0.13 to 0.18	1.6 to 2.2

Table 3

For example, the water available can be calculated for a soil with fine sandy loam in the first foot, loamy sand in the second foot and sand in the third foot. The top foot would have about 2 inches, the second foot would have about 1 inch and the third foot would have about 0.75 inch for a total of 3.75 inches of available water for a crop with a 3-foot root depth.

Soil Moisture Tension

The degree to which water clings to the soil is the most important soil water characteristic to a growing plant. This concept often is expressed as soil moisture tension. Soil moisture tension is negative pressure and commonly expressed in units of bars.

During this discussion, when soil moisture tension becomes more negative, it will be referred to as "increasing" in value. Thus, as soil moisture tension increases (the soil water pressure becomes more negative), the amount of energy exerted by a plant to remove the water from the soil also must increase. One bar of soil moisture tension is nearly equivalent to -1 atmosphere of pressure (1 atmosphere of pressure is equal to 14.7 pounds per square inch at sea level).

A soil that is saturated has a soil moisture tension of about -0.001 bars or less, which requires little energy for a plant to pull water away from the soil. At field capacity, most soils have a soil moisture tension between -0.05 and -0.33 bars. Soils classified as sandy may have field capacity tensions around -0.10 bars, while clayey soil will have field capacity at a tension around -0.33 bars. At field capacity, removing water from the soil is relatively easy for a plant.

The wilting point is reached when the maximum energy exerted by a plant is equal to the tension with which the soil holds the water. For most agronomic crops, this is about -15 bars of soil moisture tension. To put this in perspective, the wilting point of some desert plants has been measured to be between -50 and -60 bars of soil moisture tension.

The presence of high amounts of soluble salts in the soil reduces the amount of water available to plants. As dissolved salts increase in soil water, the energy expended by a plant to extract water also must increase even though the soil moisture tension remains the same. In essence, dissolved salts decrease the total available water in the soil profile.

How Plants Get Water From Soil

Water is essential for plant growth. Without enough water, normal plant functions are disturbed, and the plant gradually wilts, stops growing and dies. Plants are most susceptible to damage from water deficiency during the vegetative and reproductive stages of growth. Also, many plants are very sensitive to salinity during germination and early growth stages.

Most of the water that enters the plant roots does not stay in the plant. Less than 1 percent of the water withdrawn by the plant actually is used in photosynthesis (assimilated by the plant). The rest of the water moves to the leaf surfaces, where it transpires (evaporates) to the atmosphere. The rate at which a plant takes up water is controlled by its physical characteristics, the atmosphere and soil environment.

As water moves from the soil into the roots, through the stem, into the leaves and through the leaf stomata to the air, it moves from a low water tension to a high water tension (Figure 8). The water tension of the air is determined in large part by the relative humidity and always is greater than the water tension in the soil.

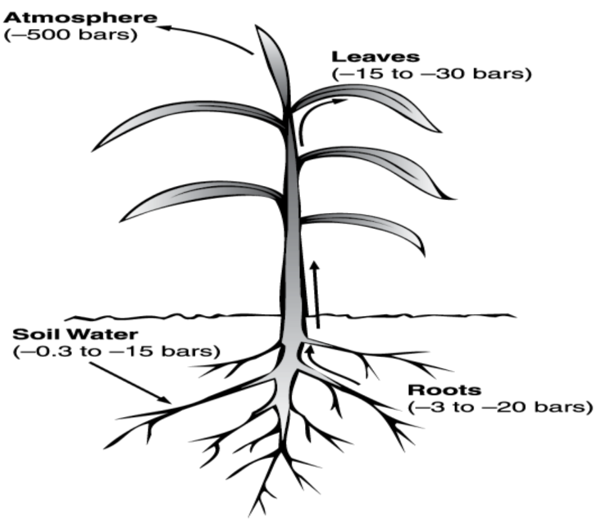


Figure 16. Illustration of the energy differentials that drive the water movement from the soil into the roots, up the stalk, into the leaves and out into the atmosphere. The water moves from a less negative soil moisture tension to a more negative tension in the atmosphere.

Plants can extract only the soil water that is in contact with their roots. For most agronomic crops, the root distribution in a deep, uniform soil is concentrated near the soil surface (Figure 9). Thus, during the course of a growing season, plants generally extract more water from the upper part of their root zone than from the lower part.

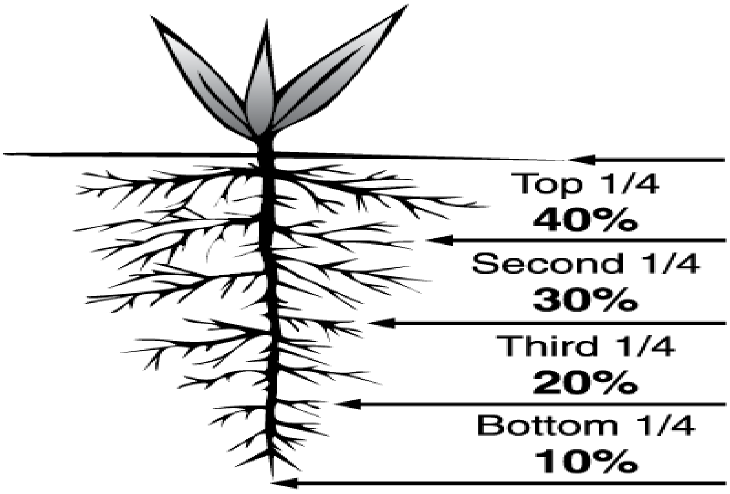


Figure 17

Figure 17. During the course of a growing season, plants will extract about 40 percent of their water from the top quarter, 30 percent from the second quarter, 20 percent from the third quarter and 10 percent from the bottom quarter of the root zone.

Plants such as grasses, which have a high root density per unit soil volume, may be able to absorb all available soil water. Other plants, such as vegetables, which have a low root density, may not be able to obtain as much water from an equal volume of the same soil. Thus, vegetables are generally more sensitive to water stress than high-root-density agronomic crops such as alfalfa, corn, wheat and sunflower.

Crop Water Use

Crop water use, also called evapotranspiration or ET, often is given as a daily estimate of the combination of the amount of water transpired by plants and the amount of evaporation from the soil surface around the plants. A plant's water use changes with a predictable pattern from germination to maturity.

All agronomic crops have a similar water use pattern (Figure 10). However, total crop water use will vary from growing season to growing season due to changes in climatic variables (air temperature, amount of sunlight, humidity, wind), and soil differences among fields (root depth, soil water holding capacities, texture, structure, etc.).

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – II – IRRIGATION ENGINEERING – SCI1401

CROP WATER REQUIREMENTS

Important Definitions Irrigation

Kharif Rabi ratio or crop ratio :The area to be irrigated for Rabi crop is generally more than that for the Kharif crop. This ratio of proposed areas, to be irrigated in Kharif season to that in the Rabi season is called, Kharif Rabi ratio. This ratio is generally 1.2 i.e. Kharif area is onehalf of the Rabi area.

Paleo irrigation: Sometims, in the initial stages before the crop is sown, the land is very dry. This particularly happens at the time of sowing of Rabi crops because of hot September, when the soil may be too dry to be sown easily. In such a case, the soil is moistened with water, so as to help in sowing of the crops. This is known as Paleo irrigation.

Korwatering: The first watering which is given to a crop, when the crop is a few centrimetres high, is called korwatering. It is usually the maximum single watering followed by other waterings at usual intervals, as required by drying of leaves.

The optimum depth of korwatering for different crops is different. For example, the optimum depth of korwatering for Rice is 19 cm. For Wheat (in U.P) is about 13.5 cm and for sugarcane is 16.5 m.

The kor'watering must be applied within a fixed limited period, called Korperiod. If the plants fail to receive this water in time or in sufficient quantity, then they do suffer a significant loss. The kor 'period depends upon the climate. It is less for humid climates and more for dry climates. The kor period for rice varies from 2 to 4 weeks, and that for wheat varies from 3 to 8 weeks.

Cash Crops:

A cash crop may be defined as crop which has to be encashed in the market for processing, etc. as it cannot be consumed directly by the cultivators. All nonfood crops, are thus, included in cash crops. Crops like jute, tea, cotton, tobacco, sugarcane etc, are therefore, called cash crops. The food crops like wheat, rice, barley , maize, etc. are excluded from the list of cash crops.

Crops rotation:

When the same crop is grown again and again in the same field, the fertility of land gets reduced as the soil becomes deficient in plant foods favourable to that particular crop. In order to enhance the fertility of the land and to make the soil regain its original structure, it is often found necessary and helpful to give some rest to the land . This can be achieved either by allowing the land to life fallow without any cultivation for some time, or to grow crop which do not mainly required those salts or foods which were mainly required by the earlier grown crop. This method of growing different crops in rotation, one after the other, in the same field, is called Rotation of Crops. A cash crop may be followed by a fodder crop, which, in turn , may be followed by a soilrenovating crop. The cultivators who are found of sowing cash crops always, should be educated and made to understand the advantages of sowing crops in rotation.

The rotation of crops will help in extracting different foods from the soil, and thus avoiding the general deficiency of any one particular type. Moreover, if only one type of crop is grown in the same field, numerous insects and pests (of similar nature) will get developed. The crop rotation will also help in checking such growths. Crop rotation will thus help in increasing the fertility of soil, and reducing the diseases and wastage due to insects, and hence increasing the overall crop yield.

In general, the following rotations of crops may be adopted depending upon the soil conditions:

(i) Wheat,Juar, Gram
(ii) Rice,'Gram
(iii) Cotton Wheat,Gram or Sugarcane
(iv) Cotton Jar ,Gram.

WATER REQUIREMENTS OF CROPS

General

Every crop requires a certain quantity of water after a certain fixed interval, throughout its period of growth. If natural rain is sufficient and timely so as to satisfy both these requirements, no irrigation water is required for raising that crop. In England, for example, the natural rainfall satisfies both these requirements for practically all crops, and therefore, irrigation is not significantly needed in England. But in a tropical country like India, the natural rainfall is either insufficient, or the water does not fall frequency of the rainfall varies throughout a tropical country, certain crop may require irrigation in certain part of the country .The area where irrigation is a must for agriculture is called the arid region, while the area in which inferior crops can be grown without irrigation is called a semiarid region.

The term ‘Water requirements of ae waycrop’inwhich amea crop requires water, from the time it is sown to the time it is harvested. It is very clear from the above discussion that the water requirement, will vary with the crop as well as with the place. Inother words, different crops will have different water requirements and the same crop may have different water requirements at different places of the same country; depending upon the climate, type of soil, method of cultivation, and useful rainfall, etc.

Crop Period or Base Period

The time period that elapses from the instant of its sowing to the instant of its harvesting is called the cropperiod. The time between the first watering of a crop at the time of its sowing to its last watering before harvesting is called the base period or the base of the crop. Crop period is slightly more than the base period, but for all practical purposes, they are taken as one and the same thing, and generally expressed in days. Hence, in future, the terms like growth period, crop period, base period etc., will be used as synonyms, each representing crop period, and will be represented crop period, and will be represented by B(in days).

Duty and Delta of a Crop

Delta: Each crop requires a certain amount of water after a certain fixed interval of time, throughout its period of growth. The depth of water required every time , generally varies from 5 to 10 cm depending upon the type of the crop . If this depth of water is required five times during the base period, then the total water required by the crop for its full growth, will be 5 multiplied by each time depth. The final figure will represent the total quantity of water required by the crop for its fullfledged nourishment.

The total quantity of water required by the crop for its full growth may be expressed in hectaremetre (Acreft) or in million cubic metres (million cubicft) or simply as depth to which water would stand on the irrigated area if the total

quantity supplied were to stand above the surface without percolation or evaporation. This total depth of water (in cm) required by a crop to come to maturity is called its delta .

Example: If rice requires about 10cm depth of water at an average interval of about 10 days, and the crop period for rice is 120 days, find out the delta for rice.

Solution:

Water is required at an interval of 10 days for a period of 120 days. It evidently means that 12 no. of waterings are required, and each time, 10 cm depth of water is required. Therefore, total depth of water required.

$$= 12 \text{ x} 10 \text{ cm} = 120 \text{ cm}.$$

Hence for rice = 120 cm. Ans.

Example: If wheat requires about 7.5 cm of water after every 28 days, and the base period for wheat is 140 days, find out the value of delta for wheat.

Solution:

Assuming the base period to be representing the crop period, as per usual practice, we can easily infer that the water is required at an average interval of 28 days up to a total period of 140days. This means that 5 no. of waterings are required. 28

The depth of water required each time = 7.5 cm.

Total depth of water required. In 140 days = 5 x7.5 = 37.5 cm

Hence,for wheat = 37.5 cm. Ans.

Delta for certain crops

The average values of deltas for certain crops are shown in table. These values represent the total water requirement of the crops. The actual requirement of irrigation water may be less, depending upon the useful rainfall. Moreover, these values represent the values on field, i.e.'delta on field' which includes losses.

Table: Average Approximate Values of Delta for Certain Important Crops in India

S.No	Crop	Delta on field
1 .	Sugarcane	120 cm
2.	Rice	120 cm
3 .	Tobacco	75 cm
4.	Wheat	40 cm

Duty of Water:

The 'duty' of water is the relationship betw it matures. This volume of water is generally expressed by: a unit discharge flowing for a time equal to the base period of the crop, called Base of a duty.

If water flowing at a rate of one cubic meter per second, runs continuously for B days, and matures 200 hectares, then the duty of water for that particular crop will be defined as 200 hectares per cumec to the base of B days. Hence, duty is defined as the area irrigated per cumec of discharge running for base period B. The duty is generally represented by the letter D.

Relation between duty and delta:

Let there be a crop of base period B days. Let one cumec of water be applied to this crop on the field for B days.

Now, the volume of water applied to this crop during B days.

Volume of water applied to crop = V = (1 x60 x60 x24 xB) m^3. = 86400 B (cubic metre)

By definition of duty (D), one cubic metre supplied for B days matures D hectares of land.

This quantity of water (V) matures D hectares of land or 10^4 D sq.m of area.

Total depth of water applied on this land

= Volume/ Area = 86,400 B/ 10^4 D . 8.64B/D metres

By definition, this total depth of water is called delta.

Delta=8.64B/D (metres)

Where,

Delta'is in cm, B is in days; and

D is duty in hectares/cumec.

During the passage of water from these irrigation channels, water is lost due to evaporation and percolation. These losses are called Transit losses or Transmission or Conveyance losses in channels.

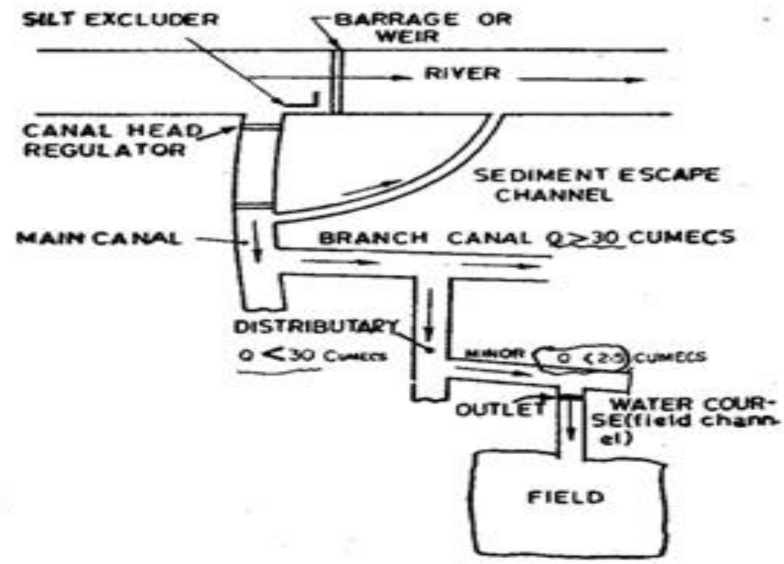

Figure 1: Layout of a canal system

Duty of water for a crop is the number of hectares of land which the water can irrigate. Therefore, if the water requirement of the crop is more, less number of hectares of land it will irrigate. Hence, if water consumed is more, duty will be less. It, therefore, becomes clear that the duty of water at the head of the watercourse will be less than the because when water flows from the head of the watercourse and reaches the field, some water islost as transit losses.

Applying the same reasoning, it can be established that duty of water at the head of a minor will be less than that at the head of the watercourse; duty at the head of a distributary will be less than that at the head of a minor, duty at the head of a branch canal will be less than that at the head of a minor, duty at the head of a main canal will be less that the duty at the head of a branch canal. Duty of water, therefore, varies from one place to another, and increases as we move downstream from the head of the main canal towards the head of the branches or watercourses. The duty at the head of watercourse (i.e. at the outlet point is generally the end point of Irrigation Department. The control of Irrigation Department finishes at the outlet point, and the water is carried into the fields through watercourses by the cultivators themselves.

Flow duty and Quantity duty:

In direct irrigation, duty is always expressed in hectares/cumec. It is then called as flow duty or duty.

In storage irrigation, duty may, sometimes be expressed in hectares/millions cubic metre of water available in the reservoir. It eventually means that every million cubic metre of water available in the reservoir will mature so many hectares of a particular crop. Hence, the irrigation capacity of the reservoir is directly known. When duty is reduced in this manner, it is called Quantity duty or Storage duty.

(i) Climatic and season: As stated earlier, duty includes the water lost in evaporation and percolation. These losses will vary with the season. Hence, duty varies from season to season, and also from time to time in the same season. The figures for duties which we generally expresses are their average values considered over the entire crop period.

(ii) Useful rainfall: If some of the rain, falling directly over the irrigated land, is useful for the growth of the crop, then so much less irrigation water will be required to mature the crop. More the useful rainfall, less will be the requirement of irrigation water, and hence more will be the duty of irrigation water.

(iii) Type of soil: If the permeability of the soil under the irrigated crop is high, the water lost due to percolation will be more and hence, the duty will be less. Therefore, for sandy soils, where the permeability is more, the duty of water is less.

(iv) Efficiency of cultivation method: If the cultivation method (including tillage and irrigation) is faulty and less efficient, resulting in the wastage of water, the duty of water will naturally be less. If the irrigation water is used economically, then the duty of water will improve, as the same quantity of water would be able to irrigate more area. Cultivators should, therefore, be trained and educated properly to use **irrigation water economically.**

Importance of duty:

It helps us in designing an efficient canal irrigation system. Knowing the total available water at the head of a main canal, and the overall duty for all the crops required to be irrigated in different seasons of the year, the area which can be irrigated can be worked out. Inversely, if we know the corps area required to be irrigated and their duties, we can work out the discharge required for designing the channel.

Irrigation Efficiencies

Efficiency is the ratio of the water output to the water input, and is usually expressed as percentage. Input minus output is nothing but losses, and hence, if losses are more, output is es and, therefore, efficiency is less. Hence, efficiency is inversely proportional to the losses. Water is lost in irrigation during various

processes and, therefore, there are different kinds of irrigation efficiencies, as given below:

(**i) Efficiency of water conveyance (η_c):** It is a ratio of the water delivered into the fields from the outlet point of the channel, to the water pumped into the channel at the starting point. It may be represented by ηc. It takes the conveyance or transit losses into account.

(ii) Efficiency of water application (η_a): It is the ratio of the quantity of water stored into the root zone of the crops to the quantity of water actually delivered into the field. it may be represented by ηa. It may also be termed as farm efficiency, as it takes into account the water is lost in the farm.

(iii) Efficiency of water storage (η_s): It is the ratio of the water stored in the root zone during irrigation to the water needed in the root zone prior to irrigation (i.e., field capacity existing moisture content). It may be represented by ηs.

Efficiency of water use (η_u): It is the ratio of the water beneficially used, including leaching water, to the quantity of water delivered. It may be represented by ηu.
Example: Once cumec of water is pumped into a farm distribution system. 0.8 cumec is delivered to a turn out, 0.9 kilometres from the well. Compute the conveyance efficiency.

Solution: By definition
$\eta_{c\,=}$ Output/ Input x 100 = 0.8/1.0 . 100 = 80%

Example: 10 cumecs of water is delivered to a 32 hectare field, for 4 hours. Soil probing after the indicated that 0.3 metre of water has been stored in the root zone. Compute the water application efficiency.

Solution:

Volume of water supplied by 10 cumecs of water applied for 4 hours =(10

=(4 60x 60)m^3 = 1,44,000 m^3

= 14.4 x10^4 m^3 = 14.4m x $10^4 m^2$ = 14. 4ha.m.

Depth of water applied = volume/area = 1,44, 000/32,0, 000

= 144 /320

= .45

∴ Input = 14.4 ha.m

Output = 32 hectares land is storing water upto 0.3 m depth,

Output = 32 x0.3 ha.m = 9.6 ha.m

Water application efficiency (ηa) = Output/ Input x 100

= 96/14.4 = 67%

(v) Uniformity coefficient or Water distribution efficiency:

The effectiveness of irrigation may also be measured by its water distribution efficiency (ηd), which is defined below:

η_d = 1d(D)

Where ηd = Water distribution efficiency

D = Mean depth of water stored during irrigation.

d = Average of the absolute values of deviations from the mean.

The water distribution efficiency represents the extent to which the water has penetrated to a uniform depth, throughout the field. When the water has penetrated uniformly throughout the field, the deviation from the mean depth is zero and water distribution efficiency is 1.0.

Example: A stream of 130 litres per second was diverted from a canal and 100 litres per second were delivered to the field. An area of 1.6 hectares was irrigated in 8 hours. The effective depth of root zone was 1.7 m. The runoff loss in the field was 420 cu. M. The depth of water penetration varied linearly from 1.7 m at the head end of the field to1.1 m at the tail end. Available moisture holding capacity of the soil is 20 cm per metre depth of soil. It is required to determine the water conveyance efficiency, water application efficiency, water storage efficiency, and water distribution efficiency. Irrigation was started at a moisture extraction level of 50% of the available moisture.

Solution:

(i) Water conveyance efficiency (ηC)

=(Water delivered to the fields/ Water supplied into the canal at the head) x 100

= 100/130 x 100 =77%

(ii)Water application efficiency (ηa)

Water stored in the root zone during irrigation / Water delivered to the field x 100

Water supplied to field during 8 hours @ 100 litres per second

= 100x8 x60 x 60 litres = 2880 cu. m.

Runoff loss in the field = 420 cu. M.

the water stored in the root zone

= 2880-420 = 2460 cu. m.

Water application efficiency (ηa)

= 2460 /100 = 85.4% Ans. 2880

Storage efficiency

= (Water stored in the root zone during irrigation /

Water needed in the root zone prior to irrigation) x 100

Moisture holding capacity of soil

= 20 cm per m depth x1.7 m depth of root zone = 34 cm

Moisture already available in the root zone at the time of start of irrigation

50/100 x 34 =17cm.

Additional water required in the root zone

= 34 -17 = 17 cm.

= 2720 cu. m.

But actual water stored in root zone = 2460 cu. m.

Water storage efficiency (ηs)

=2460 /2720 x 100 90% (say)

(iv) Water distribution efficiency

Where D = mean depth of water stored in the root zone

D = (1.7+1.1)/2 = 1.4m

d is computed as below:

Deviation from the mean at upper end (absolute value) = |1.7 -1.4| = 0.3

Deviation from the mean at lower end = | 1.1 -1.4 | =0.3

d = Average of the absolute values of deviations from mean =

0.4 +0.3/2 = 0.35

Using equations, we have,

η_{d} = 75 or 75% Ans.

Consumptive Use or Evapotranspiration (Cu)

Consumptive use for a particular crop may be defined as the total amount of water used by the plant in transpiration (building of plant tissues, etc.) and evaporation from adjacent soils or from plant leaves, in any specified time. The values of consumptive use (Cu) may be different for different crops, and may be different for the same crop at different times and places.

In fact, the consumptive use for a given crop at a given place may vary throughout the day, throughout the month and throughout the crop period. Values of daily consumptive use or monthly consumptive use, are generally determined for a given crop and at a given place. Values of monthly consumptive use over the entire crop period are then used to determine the irrigation requirement of the crop.

Effective Rainfall (Re)

Precipitation falling during the growing period of a crop that is available to meet the evapotranspiration needs of the crop, is called effective rainfall. It does not include precipitation lost through deep percolation below the root zone or the water lost as surface run off. Average ratios, applicable to effective rainfall, are shown in table.

Consumptive Irrigation Requirement (CIR)

It is the amount of Irrigation water required in order to meet the evapotranspiration needs of the crop during its full growth. It is, therefore, nothing but the consumptive use itself, but exclusive of effective precipitation, stored soil moisture, or ground water. When the last two are ignored, then we can write

$$CIR = Cu \quad Re$$

Net Irrigation Requirement (NIR)

It is the amount of irrigation water required in order to meet the evapotranspiration need of the crop as well as other needs such as leaching. Therefore, N.I.R. = CuRe + Water lost as percolation in satisfying other needs such as leaching.

Factors Affecting Consumptive Use

Consumptive use or evapotranspiration depends upon all those factors on which evaporation and transpiration depend; such as temperature, sunlight, humidity, wind movement, etc, as detailed in article.

Example: The following table gives the values of consumptive uses and effective rainfalls for the periods shown against them, for a Jowar crop sown at Bellary in Karnataka State. The period of growth is from 16^{th} October to 2^{nd} Feb., i.e. (110 days). Determine the net irrigation requirement of this crop, assuming that water is not required for any other purpose except that of fulfilling the evapotranspiration needs of the crop.

Estimation of Consumptive Use:

Although various methods have been developed in order to estimate evapotranspiration (consumptive use) value of a crop in an area, but the most simple and commonly used methods are:

(1) Blaney Criddle Equation, and

(2) Hargreaves class A pan evaporation method. They are described below:

1. BlaneyCriddle Formula. It sates that the monthly consumptive use is given by

$$C_u = {}^{k.p} / 40 \ [1.8t + 32]$$

where, C_u = Monthly consumptive use in cm.

k = Crop factor, determined by experiments for each crop, under the environmental conditions of the particular area.

t = Mean monthly temperature in ^{o}C.

p = Monthly pet cent of annual day light hours that occur during the period.

If p/40 [1.8t +32]is represented by f, we get

$$Cu = k.f \qquad ...(2.6)$$

Consumptive irrigation requirement

$= C_u - R_e = 32.72 - 8.38 = 24.34$ cm.

Field irrigation requirement = C.I.R./ η_a

$= 24.34/0.8 = 30.43$ cm.

SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVL ENGINEERING

UNIT – III – IRRIGATION ENGINEERING – SCI1401

IRRIGATION SYSTEM COMPONENTS

COMPONENTS OF IRRIGATION NETWORK

Irrigation Network

Irrigation network represents the network of permanent and temporary waterways (canals, pipelines) that supply water to irrigated lands from an irrigation source.It is the key component of the irrigation system. It consists of conducting and regulatory networks.It is equipped with the devices and facilities for water measurement (water gauges), rising of water level in canals, and control of water discharge (head regulators, checks), connection of canal reaches (check drops, chutes), retention of silt/debris (sediment tanks, guide systems), and so forth.

Canal structures are components of irrigation network;

- Head works,
- Control structure,
- Cross – drainage work,
- Bridges and culverts,
- Canal outlets

Head works

An irrigation canal takes its supplies from rivers or stream. In order to divert water from the river into the canal it is necessary to construct certain works or structures across the river at the head of off taking canal. These works are known as canal head works or head works.

Canal need works are classified into following two types:

1. Storage head works
2. Diversion head works

Storage head works

- It consists of a dam constructed across the river to create a reservoir in which water is stored during the period of excess flow into river.
- Storage head works stores water in addition to its diversion into canals.

Diversion head works

- It serves to raise the water level into river and divert the required quantity into canal. Various function served by a diversion head works are as follow.
- It rises water level in the river so that command area increase.
- It regulates supply into the canal.

- It controls entry of silt into canal .
- It provides some storage for a short period.

Canal Regulator

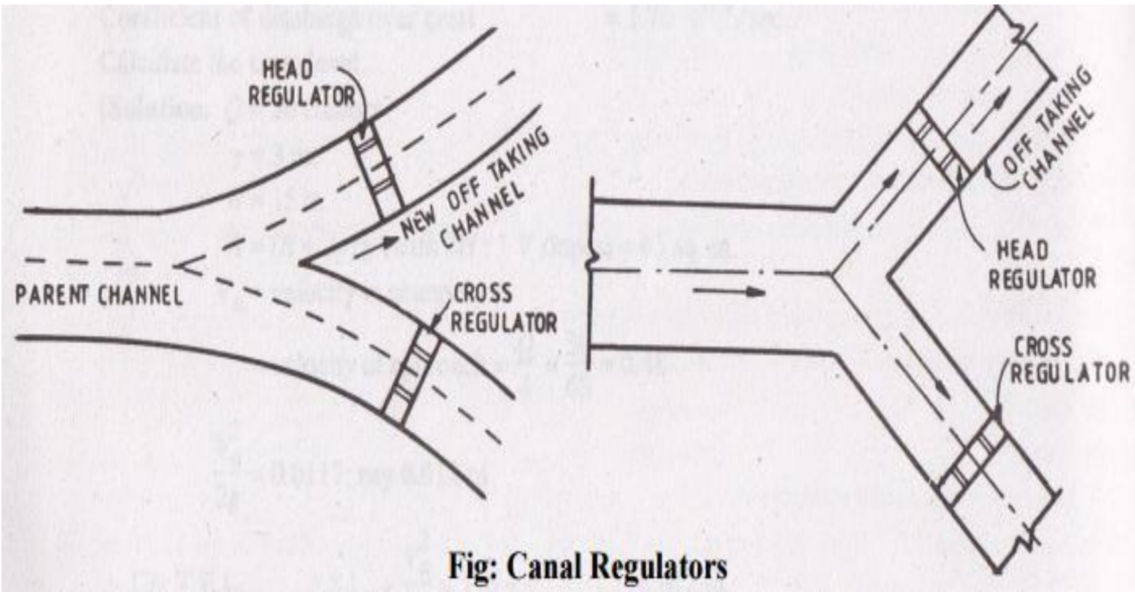

Fig: Canal Regulators

Figure 1: Canal Regulators

- A head regulator provided at the head of the off-taking channel, controls the flow of water entering the new channel.
- While a cross regulator may be required in the main channel downstream of the off-taking channel, and is operated when necessary so as to head up water on its upstream side, thus to ensure the required supply in the off-taking channel even during the periods of low flow in the main channel.

Main functions of a head regulator:

- To regulate or control the supplies entering the off- taking canal
- To control the entry of silt into the off-taking canal
- To serve as a meter for measuring discharge.

Main functions of a cross regulator:

- To control the entire Canal Irrigation System.
- To help in heading up water on the upstream side and to fed the off-taking canals to their full demand.
- To help in absorbing fluctuations in various sections of the canal system, and in preventing the possibilities of breaches in the tail reaches. Cross regulator is often combined with bridges and falls, if required.

Components of irrigation structures – regulation works:

- Regulation works which includes falls, off take structure, cross regulator and distributory head regulator.
- Canal Falls.
- Surplus water escape.
- Canal outlets.

CROSS DRAINAGE WORK

In an irrigation project, when the network of main canals, branch canals, distributaries, etc. are provided, then these canals may have to cross the natural drainages like rivers, streams, etc at different points within the command area of the project.

The crossing of the canals with such obstacle cannot be avoided. So, suitable structures must be constructed at the crossing point for the easy flow of water of the canal and drainage in the respective directions. These structures are known as cross- drainage works.

Necessity of Cross – Drainage works

- The water-shed canals do not cross natural drainages. But in actual orientation of the canal network, this ideal condition may not be available and the obstacles like natural drainages may be present across the canal. So, the cross drainage works must be provided for running the irrigation system.
- At the crossing point, the water of the canal and the drainage get intermixed. So, far the smooth running of the canal with its design discharge the cross drainage works are required.
- The site condition of the crossing point may be such that without any suitable structure, the water of the canal and drainage can not be diverted to their natural directions.

Types of Cross-Drainage Works:

- Type I (Irrigation canal passes over the drainage)
    - Aqueduct
    - Siphon aqueduct
- Type II (Drainage passes over the irrigation canal)
    - Super passage
    - Siphon super passage
- Type III (Drainage and canal intersection each other of the
- same level)
    - (a) Level Crossing
    - (b) Inlet and outlet

Selection of type of cross-drainage works

- Relative bed levels
- Availability of suitable foundation
- Economical consideration
- Discharge of the drainage
- Construction problems

Aqueduct :

The aqueduct is just like a bridge where a canal is taken over the deck supported by piers instead of a road or railway. Generally, the canal is in the shape of a rectangular trough which is constructed with reinforced cement concrete. Sometimes, the trough may be of trapezoidal section.

- An inspection road is provided along the side of the trough.
- The bed and banks of the drainage below the trough is protected by boulder pitching with cement grouting.
- The section of the trough is designed according to the full supply discharge of the canal.

- A free board of about 0.50 m should be provided.
- The height and section of piers are designed according to the highest flood level and velocity of flow of the drainage.
- The piers may be of brick masonry, stone masonry or reinforced cement concrete deep foundation (like well foundation) is not necessary for the piers. The concrete foundation may be done by providing the depth of foundation according to the availability of hard soil.

Siphon Aqueduct

- In a hydraulic structure where the canal is taken over the drainage, but the drainage water cannot pass clearly below the canal. It flows under siphonic action. So, it is known as siphon aqueduct. This structure is suitable when the bed level of canal is below the highest flood level.

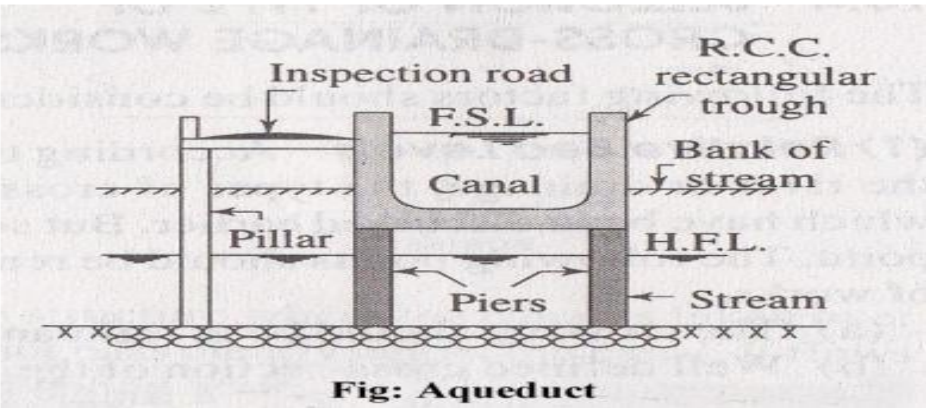

Fig: Aqueduct

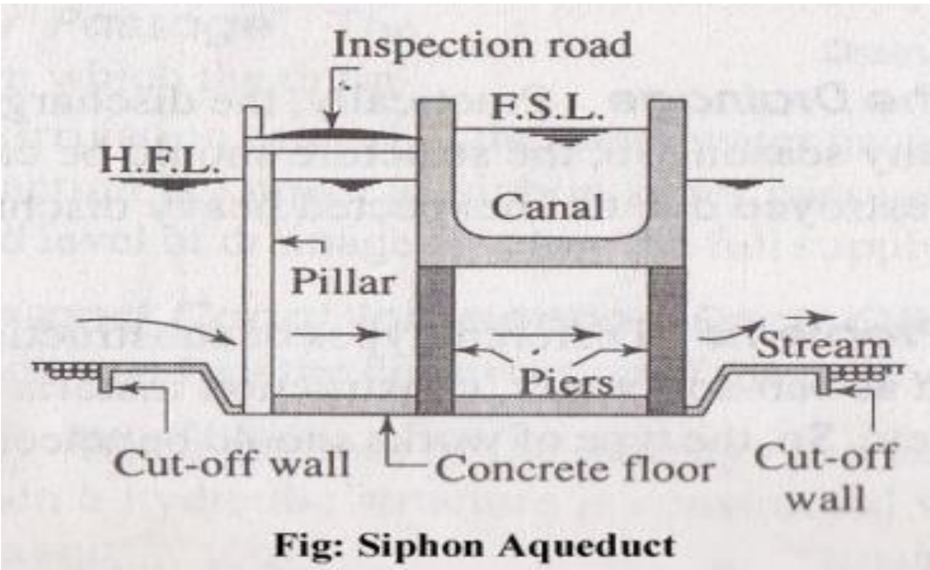

Fig: Siphon Aqueduct

Figure 2: Siphon Aqueduct

Super Passage

The super passage is just opposite of the aqueduct. In this case, the bed level of the drainage is above the fully supply level of the canal. The drainage is taken through a rectangular or trapezoidal trough of channel which is constructed on the deck supported by piers. The section of the drainage trough depends on the high flood discharge. A free board of about 1.5 m should be provided for safety. The trough should be constructed of reinforced cement concrete. The bed and banks of the canal below the drainage trough should be protected by boulder pitching or lining with concrete slabs. The foundation of the piers will be same as in the case of aqueduct.

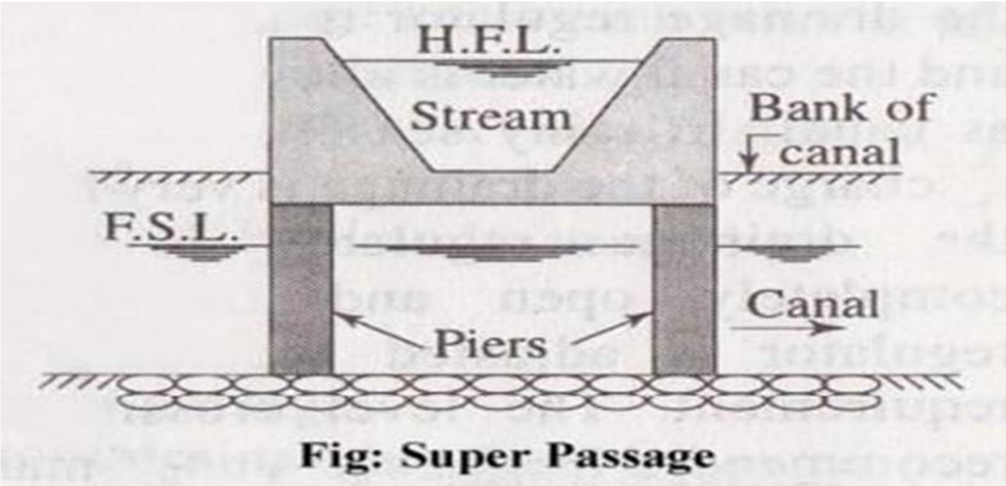

Figure 3: Super Passage

Siphon Super Passage

It is just opposite siphon aqueduct. In this case, the canal passes below the drainage trough. The section of the trough is designed according to high flood discharge. The bed of the canal is depressed below the bottom level of the drainage trough by providing sloping apron on both sides of the crossing. The sloping apron may be constructed with stone pitching or concrete slabs. The section of the canal below the trough is constructed with cement concrete in the form of tunnel which acts as siphon. Cut-off walls are provided on upstream and downstream side of sloping apron. Other components are same as in the case of siphon aqueduct.

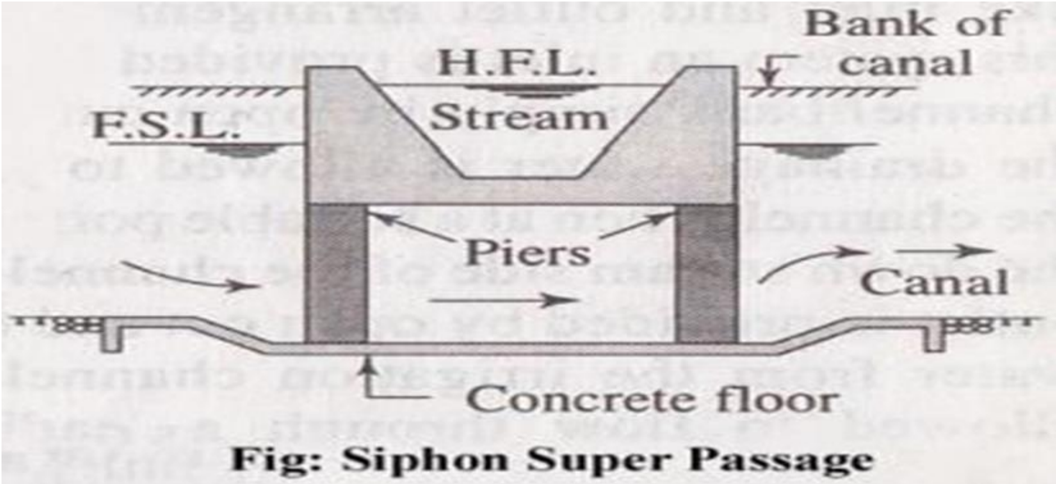

Figure 4: Siphon Super Passage

Level Crossing

The level crossing is an arrangement provided to regulate the flow of water through the drainage and the canal when they cross each other approximately at the same bed level. The level crossing consists of the following components:

Crest Wall: It is provided across the drainage just at the upstream side of the crossing point. The top level of the crest wall is kept at the full supply level of the canal.

Drainage Regulator: It is provided across the drainage just at the downstream side of the crossing point. The regulator consists of adjustable shutters at different tiers.

Canal Regulator: It is provided across the canal just at the downstream side of the crossing point. This regulator also consists of adjustable shutters at different tiers.

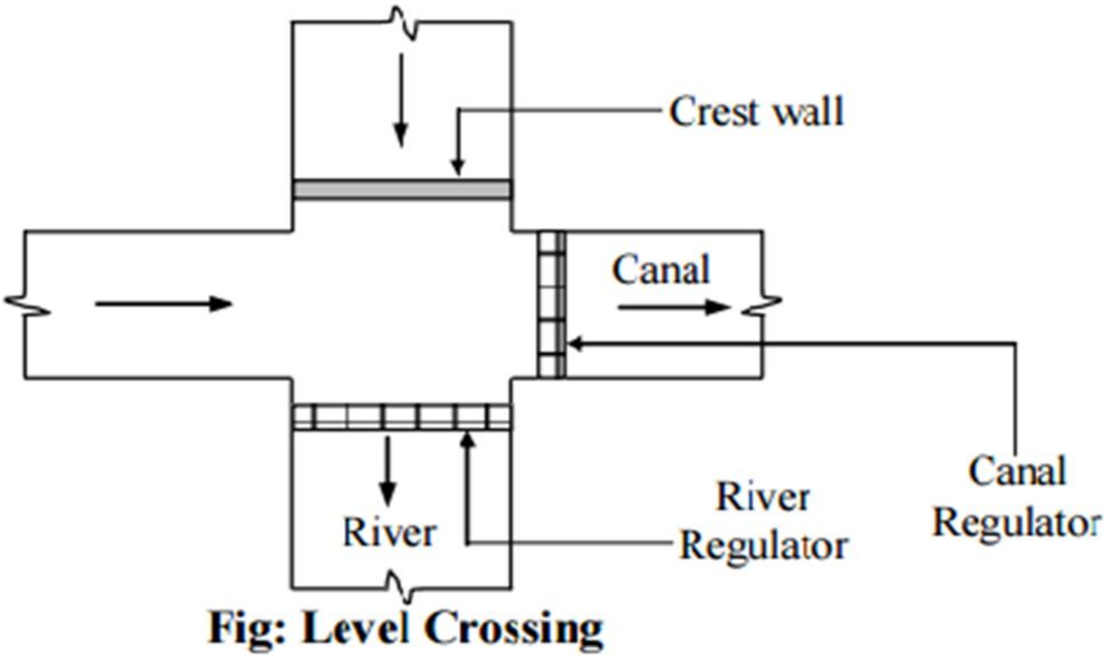

Figure 5: Level Crossing

- Inlet and outlet: In the crossing of small drainage with small channel no hydraulic structure is constructed. Simple openings are provided for the flow of water in their respective directions. This arrangement is known as inlet and outlet.
- In this system, an inlet is provided in the channel bank simply by open cut and the drainage water is allowed to join the channel. At the points of inlet and outlet, the bed and banks of the drainage are protected by stone pitching.

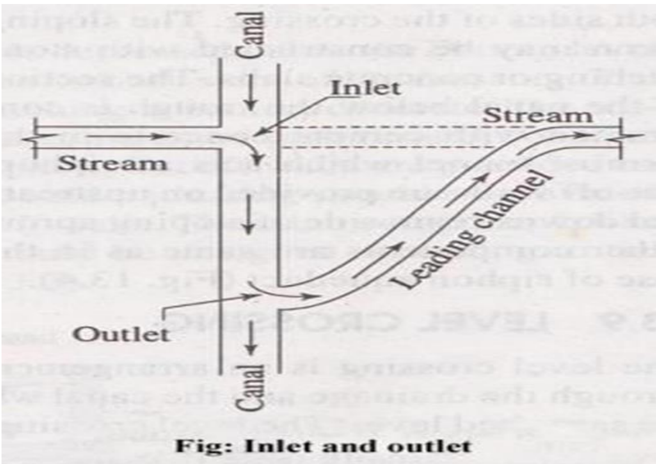

Figure 6: Inlet and Outlet

Canal Escapes:

It is a side channel constructed to remove surplus water from an irrigation channel (main canal, branch canal, or distributary etc.) into a natural drain.

The water in the irrigation channel may become surplus due to

Mistake

Difficulty in regulation at the head Excessive rainfall in the upper reaches

Outlets being closed by cultivators as they find the demand

of water is over.

Types of Canal Escapes:

(a) Weir type escape

(b) Regulator/sluice type escape

Weir type escape:

Crest level = FSL of the canal Water escapes if W_L > FSL

The crest of the weir wall is kept at R.L equal to canal FSL.

When the water level rises above FSL, it gets escaped.

Regulator/sluice type escape:

- The silt of the escape is kept at canal bed level and the flow can be used for completely emptying the canal.

They may be constructed for the purpose of scouring off excess bed silt deposited in the head reaches from time to time.

Weir type escape

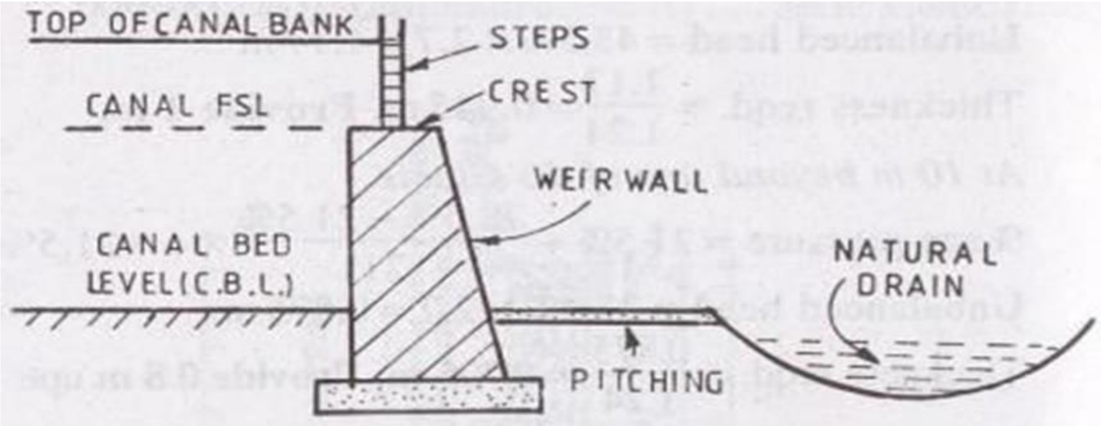

Figure 7: Weir escape

Regulator / Sluice type escape

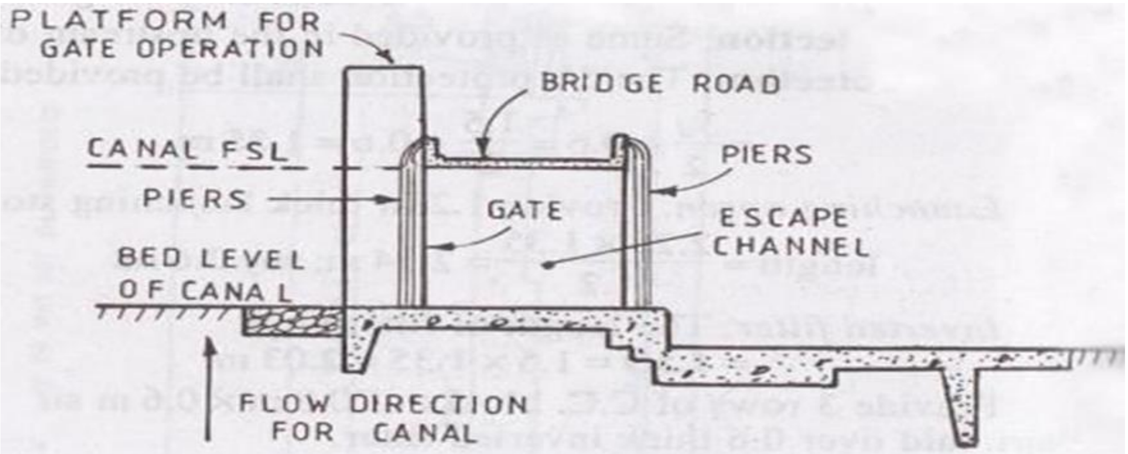

Figure 8: Sluice type Escape

Canal Outlets: A canal outlet is a small structure built at the head of the water course so as to connect it with a minor or a distributory channel. It acts as a connecting link between the system manager and the farmers.

Requirements of a good module:

- It should fit well to the decided principles of water distribution.
- It should be simple to construct.
- It should work efficiently with a small working head.
- It should be cheaper.
- It should be sufficiently strong with no moving parts, thus avoiding periodic maintenance.
- It should e such as to avoid interference by cultivators.
- It should draw its fair share of silt.

- Types of outlets/modules:
- Non-modular module: Non-modular modules are those through which the discharge depends upon the head difference between the distributary and the water course. Common examples are: (i) Open sluice (ii) Drowned pipe outlet

Lowering of the bed of the water course will draw extra discharge. Thus equitable distribution of discharge may not be possible.

- Semi-modules or Flexible modules: Due to construction, a super-critical velocity is ensured in the throat and thereby allowing the formation of a jump in the expanding flume. The formation of hydraulic jump makes the outlet discharge independent of the water level in water course, thus making it a semi module.

Semi-modules or flexible modules are those through which the discharge is independent of the water level of the water course but depends only upon the water level of the distributory so long as a minimum working head is available.

Examples are pipe outlet, open flume type etc

- Rigid modules or Modular Outlets: Rigid modules or modular outlets are those through which discharge is constant and fixed within limits, irrespective of the fluctuations of the water levels of either the distributory or of the water course or both.

An example is Gibb's module.

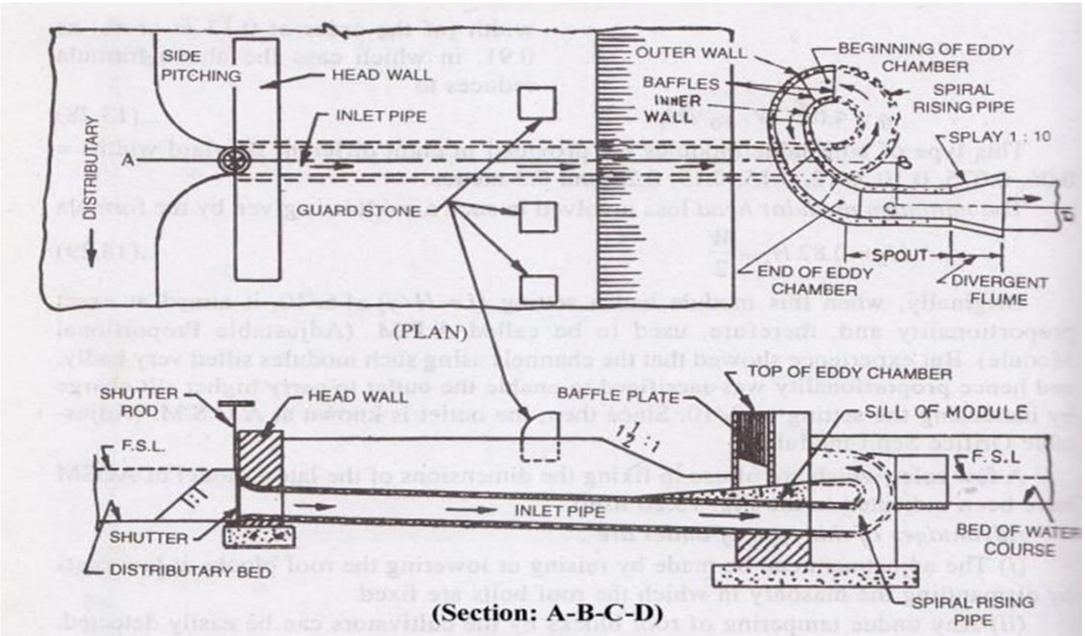

Figure 9: Gibbs Module

SELECTION OF TYPE OF CROSS DRAINAGE WORK

The following factors should be considered:

(i) Relative Bed Level

According to the relative bed levels of the canal and the river or drainage, the type of cross drainage work are generally selected which has been discussed earlier. But some problems may come at the crossing point

The following points should be remembered while recommending the type of work,

(a) The crossing should be at right angle to each other,

(b) Well defined cross-section of the river or drainage should be available.

(c) At the crossing point the drainage should be straight for a considerable length.

(d) The width of the drainage should be narrow as far as possible.

Considering the above points The C/s can be shifted to the downstream or upstream.

(ii)Availability of Suitable Foundation

For the construction of cross drainage works suitable foundation is required. By boring test, if suitable foundation is not available, then the type of cross drainage work should be selected to site Condition.

(iii)Economic Consideration

The cost of construction of cross drainage works should be justified with respect to the project cost and overall benefits of the project. So, the type of works should be selected considering the economical point of view.

(iv) Discharge of the drainage

Practically the discharge of the drainage is very uncertain in rainy season. So, the structure should be carefully selected so that it may not be destroyed due to unexpected heavy discharge of the river or drainage.

(v) Construction of Problems

Different types of constructional problems may arise at the site such as sub soil water, construction materials, communication, availability of land etc. So the type of works should be selected according to the site condition.

DESIGN OF CROSS DRAINAGE WORKS

1. Determination of maximum flood discharge.
2. Determination of water way of the drain.
3. Contraction of canal water way if canal is to be flumed.
4. Head loss through syphon barrels.
5. Determination of uplift pressure on the bed of canal of drain whichever is above.
6. Determination of uplift pressure on the bed of canal or drain whichever is below.
7. Design of bank connections.

Besides the design of these elements, structural design of foundation, piers, abutment, syphon barrels, etc. also have to be done.

1.DETERMINATION OF MAXIMUM FLOOD DISCHARGE

- The high flood discharge for smaller drain can be worked out by using empirical formulas; and for large drains other methods such as Hydrograph analysis, Rational formula, etc may be used.
- In general the methods used in the estimation of the flood flow can be group as:
- Physical Indications of past floods
- Empirical formulae and curves
- Overland flow hydrograph and unit hydrograph.

Empirical Formulas

Several empirical formula have been developed for estimating the maximum or peak value of flood discharge. In these formulae the maximum flood discharge Q of a river is expressed as a function of the catchment area A. Most of these formulae may be written in a general form as:

- $Q = C A^n$

Where, C is coefficient and n is index, Both C and n depend upon various factor, such as

(i) Size ,shape and location of catchment ,
(ii) Topography of the catchment,
(iii) intensity and duration of rainfall and distribution pattern of the storm over catchment area.

- **Dicken's formula:**

  Q = CA ¾

  Where,

  Q= Maximum flood Discharge in cumec. A= Area of Catchment in sq. Km

  C= coefficient depending upon the region The maximum value of C= 25.

- **Ryve's Formula:**

  $Q= CA^{2/3}$

  Where, Q= discharge in cumec

  A= Catchment Area in Sq. . Km

  C= coefficient depending upon the region

2.Determination of Water Way of the Drain:

- After having decided about the maximum flood discharge, water way for the drain can be easily fixed by following Lacey's equation-
- $P = 4.75 \sqrt{Q}$
- For large drains, the perimeter (P) may be assumed equal to the width of the river. A contraction upto 20% of water way may be allowed in case of small drains. In large drains, no extra provision is made for the area covered by the piers.

3. Velocity of Flow through Barrel:

The velocity of flow through the barrel may range from 2 m/sec to 3 m/sec, The reason for selecting this range is that the lower velocities may cause silting in the barrels. Whereas when the velocity is higher than 3 m/sec the bed load may cause abrasion of the barrel floor and subsequently it may be damaged.

4.Height of Opening:

Once the waterway discharge and velocity are fixed the depth of flow may be obtained easily. There should be sufficient headway or clearance left between the HFL and the bottom of the canal bed. A clearance of 1 m or half the height of the culvert, whichever is less would be sufficient. Hence, Height of opening = Depth of flow + Clearance or headway.

5. Number of Spans:

After determining the total length of an aqueduct between the abutments number of spans to be provided may be fixed on the basis of the following two considerations:

i. Structural strength required, and

ii. Economical consideration.

For example, when arches are used the number of spans to be provided may be more. When the cost of construction in the foundation is rather high, small number of spans should be adopted and then RCC beams may be used.

6.Contraction of Canal Water Way:

Contraction of canal is required only where type III aqueduct is to be installed. Fluming of the canal requires the provision of extra transition wings for joining the flumed portion to the normal section.

While fluming the canal following points should be taken care of:

(i) The velocity of flow through the flumed section of the canal is not more than 3 m/sec.

(ii) The flow should remain sub-critical without any formation of hydraulic jump.

(iii) The approach transition wings should not be steeper than 30° (splay of 2 :1) and departure transition should not be steeper than 22 ½° (splay of 3:1).

(iv) The transitions are curved and flared so that there is minimum loss of head and the flow is streamlined

Length of convergence: It can be fixed after fixing the convergence ratio. The convergence ratio is generally taken as 2: 1 (horizontal: lateral), i.e., not steeper than 30°

Length of Expansion or Departure Transition:

Length of expansion on the downstream side of the aqueduct may be fixed after knowing the expansion ratio. The expansion ratio is generally taken as 3 : 1 (horizontal : lateral), i.e., not steeper than 22.5°. To maintain streamlined flow and also to reduce loss of head the transitions are generally made up of curved and flared wing walls.

The transitions can be designed for following two conditions:

(a) Depth of water remains constant.

(b) Depth of water varies.

(a) Depth of Water Remains Constant:

For this design, following two formula may be used.

(i) R.S. Chaturvedis's semi-cubical parabolic transition-

The values of x can be found out by choosing various convenient values of B_x.

$$x = \frac{L_f B_0^{3/2}}{B_0^{3/2} - Bf^{3/2}} \left\{ 1 - \left(\frac{B_f}{B_x} \right)^{3/2} \right\} \qquad (25.2)$$

(ii) AC Mitra's hyperbolic transition-

$$B_x = \frac{B_0 B_f L_f}{L_f B_0 - x(B - B_f)} \qquad (25.3)$$

The value of B_x can be found out by choosing various values of x.

In both the formulae, (Chaturvedis's and Mitras)

B_0 = normal width of the canal

B_f = Flumed width of the canal

B_x = Width at any distance x from the flumed section.

L_f = Total length of transition.

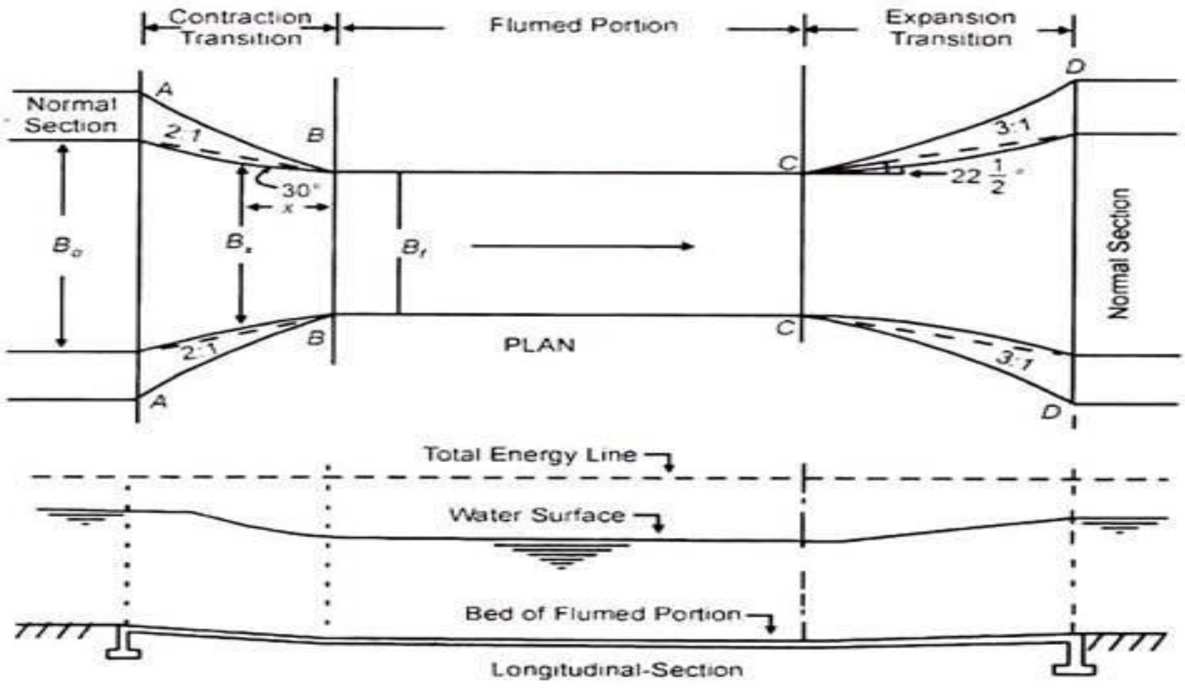

Fig. 25.8

Figure 10: Cross Drainage Work

(b) Depth of Water Varies:

When depth of water varies, the design of transition is done by Hind's method.

Consider Fig. 25.8. Let A-A and B – B be the sections of canal on the entrance side and C – C and D-D on the exit side. A – A and D-D are the normal sections of the canal and B – B and C – C are the flumed sections of the canal

Let D_A, D_B, D_c and D_D are the depths and V_a, V_h, V_c, V_d, the corresponding velocities of flow at sections A – A, B – B, C – C, and D-D respecting. See Fig. 25.8.

Design is started from the D/S side i.e., from section D-D.

1. Let bed level and cross-section of the canal at section D-D is completely known.

Level of water surface at $D - D$

$$= \text{Level of bed at } D - D + D_d$$

T.E.L. at section $D - D$

$$= \text{Level of bed at } D - D + D_d + \frac{V_d^2}{2g}$$

2. Loss of energy in expansion from section C – C to D – D is taken-

$0.3\ [(V^2_c - V^2_d/2g)]$

Neglecting friction losses between section $C - C$ and $D - D$.

$$\text{T.E.L. at } C - C = \text{T.E.L. at } D - D + 0.3\left(\frac{V_c^2 - V_d^2}{2g}\right)$$

$$\text{Level of water at CC} = \text{T.E.L. at } C - C - \frac{V_c^2}{2g}.$$

Bed level at CC = Level of water at CC – D_c.

3. The flumed channel section between B -B and C-C remains constant and no loss, other than friction occurs in it which can be worked out using Manning's formula-

$$Q = \frac{A\ R^{2/3}\ S^{1/2}}{N}$$

$\therefore$ T.E.L. at $B-B$ = T.E.L. at CC + head loss.

Level of water at $B-B$ = T.E.L. at $B-B-\frac{V_b^2}{2g}$.

Bed level of channel at $B-B$

$$= \text{Level of water at } B-B-D_b.$$

Since velocity and depth are constant in the flumed portion, T.E.L, level of water surface and level of bed are parallel to each other between sections B – B and C-C.

4. Loss of energy of head between section B – B and A – A due to contraction is taken 0.2 $(V^2_b - V^2_a/2g)$

Neglect friction losses.

$$\text{T.E.L. at } A - A = \text{T.E.L. at } B - B + 0.2\left(\frac{V_b^2 - V_a^2}{2g}\right).$$

$$\text{Level of water at } A - A = \text{T.E.L. at } A - A \ \frac{V_a^2}{2g}.$$

$$\text{Level of bed at } A - A = \text{Level of water at } AA - D_a.$$

5. Now bed level, water surface level and T.E.L. for all the four sections are known. The T.E.L. may be drawn straight between adjacent sections. The bed levels are also joined by straight line. If there is any fall it is provided either by rounding off the corners or with smooth reverse curve tangential to the bed. Smooth reverse curve is provided where drop in the bed levels is appreciable.

Uplift Pressure on the Underside of the trough or the Barrel Roof

Uplift Pressure on the Barrel Roof

- The amount of the uplift pressure exerted by the drain water on the roof of the culvert can be evaluated by drawing the hydraulic Gradient line (H.G).
- The uplift pressure at any point under the roof of the culvert will be equal to the vertical ordinate between hydraulic gradient line and the underside of the canal trough at that point From the uplift diagram it is very evident that the maximum uplift occurs at the upstream end point near the entry. The slab thickness should be

designed to withstand this maximum uplift.

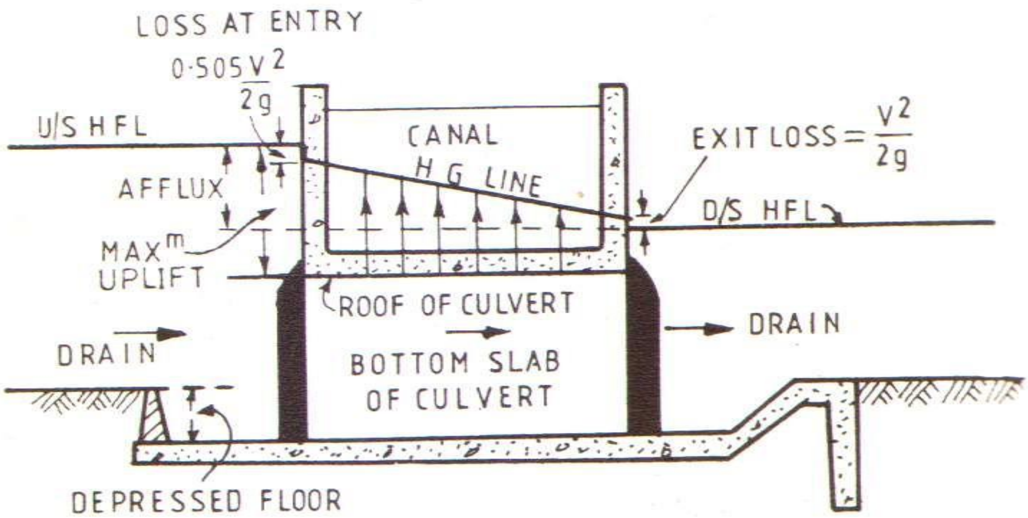

Figure 11: Uplift pressure on the roof of the barrel

- The floor of the aqueduct or siphon is subjected to uplift due to two cases:
- (a) Uplift due to Water-Table: This force acts where the bottom floor is depressed below the drainage bed, especially in syphon aqueducts.
- The maximum uplift under the worst condition would occur when there is no water flowing in the drain and the watertable has risen up to the drainage bed. The maximum net uplift in such case would be equal to the difference in level between the drainage bed and the bottom of the floor.

Uplift Pressure due to Seepage of water from the canal to the drainage

- The maximum uplift due to this seepage occurs when the canal is running full and there is no water in the drain. The computation of this uplift due to this seepage occurs when the canal is running full and there is no water in the drain. The computation of this uplift, exerted by the water seeping from the canal on the bottom of the floor, is very complex and difficult, due to the fact that the flow takes place in three dimensional flow net. The flow cannot be approximated to a two dimensional flow, as there is no typical place across which the flow is practically two dimensional. Hence, for smaller works, Beligh's Creep theory may be used for assessing the seepage pressure, But for larger works, the uplift pressure must be checked by model studies.

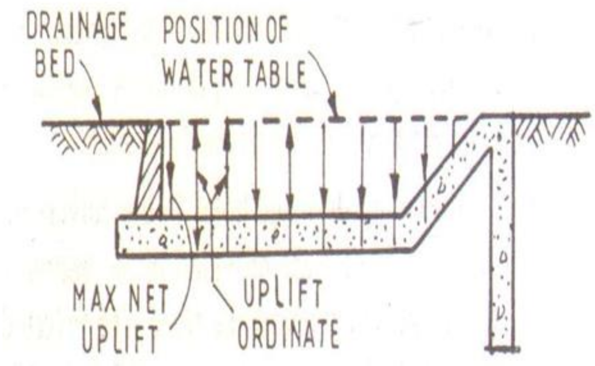

Figure 12: The floor of the Aqueduct of siphon subjected to uplift

DESIGN OF BANK CONNECTIONS

- Two sets of wings are required in aqueducts and syphon-

aqueducts. These are:

- Canal wings or Land wings
- Drainage Wings or Water Wings
- Canal Wings: These wings provide a strong connection between masonary or concrete sides of a canal trough and earthen canal banks. These wings are generally warped in plan so as to change the canal section from trapezoidal to rectangular. They should be extended upto the end of splay. These wings may be designed as retaining walls for maximum differential earth pressure likely to come on them with no water in the canal. The foundations of these wings should not be left on filled earth. They should be taken deep enough to give safe creep length.

Canal Wing

Canal wing walls on the upstream and downstream side of the aqueduct protect and retain the earth in the canal banks. The foundation of the canal wing walls should not be left in the embanked earth. The wing walls should be based on the sound foundation in the natural ground. In the transitions the side slopes of the natural section (generally 11/2: 1) are warped to conform with shape (generally vertical) of the trough over the drain.

Drainage wing walls are provided on the upstream and downstream of the barrel to protect and to retain the natural sides of the drain. As the bed of the drain gets scoured during floods the drainage wing walls should be taken deep into the foundation below maximum scour depth. The wing walls should be taken back sufficiently into the top of the guide banks. The wing walls should be designed to permit smooth entry and exit of the flow in the drain.

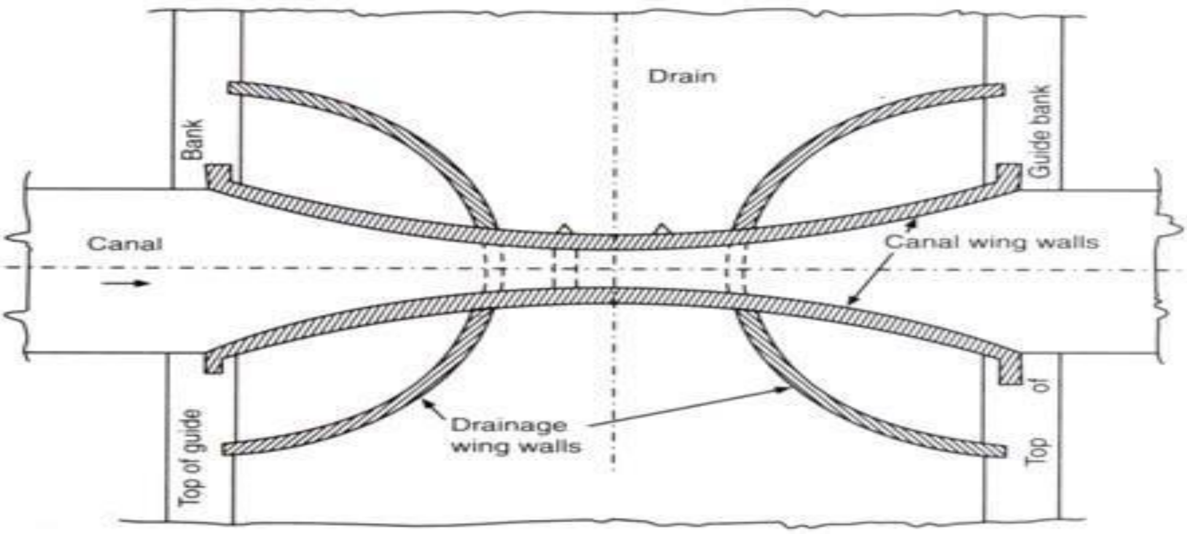

Fig. 19.24. Arrangement of wing walls

Figure 13: Arrangement of wing wall

CANAL LINING

Based on lining:

i. Lined canals
ii. Unlined canals

Lined canals:

Provided with impervious bed and bank prevents seepage velocity of flow is on one.

Lining reduces the cross section area of canal.

Unlined canals:

Bed and banks are made of natural soil through which it is constructed velocity of flow is low.

Advantages:

- Reduces seepage loss- saves water
- Prevents water slogging
- High velocity of flow
- Does not allow sediments to deposit
- Prevents weed growth
- Less evaporation loss
- Saves land for canal construction
- Cost of canal structures is less as width is less
- High velocity, so flat hydraulic gradient more heat for power house.
- Area of C.S of lined channel is less
- Leaching of salts from sides prevented
- Maintenance cost is less.
- Stable channel is easy to operate.

Disadvantages:

- Lining require high initial cost
- Difficult to repair drainage
- Canal to lining outlets cannot be shifted
- Has no perms, hence *shift* on the banks is not easy

Types of lining :

Hard surface lining

Cast insitu Cement concrete lining(insite)

Precast concrete lining.

Cement concrete tile lining or brick lining

Short Crete lining (Sprayed concrete, 3.5 cm thickness)

Asphaltic concreting

Earth lining:

Compacted earth lining (30 to 90 cm thickness)

Soil- cement lining. (2 to 8 %)

DESIGN OF UNLINED CANAL

KENNEDY'S THEORY

Regime Channel

Non silting , non-scouring channel is that, whatever silt has entered the channel at its head is kept in suspension, so that it does not settle down and deposit at any point of channel. Moreover the velocity of the water should be such that it does not produce local silt by erosion of channel bed and slopes.

Upper bari doab canal

$V_0 = C_1.Y^{C2}$

DESIGN PROCEDURE (KENNEDY'S THEORY)

TYPE 1 Q, N, m and s

Assume trial value of D in meters

* Calculate the velocity V using Kennedy's eqn $V = 0.55\ m\ Y^{0.64}$
* Get area of section $A = Q/V$

Knowing D and A, calculate the bed width B

The side slope of the canal in alluvial soil assumed to be ½:1 when the canal has run for some time.

$A = BD + (D^2/2)$ from which B can calculated

$$R = \frac{A}{P} = \frac{BD + \frac{D^2}{2}}{B + D\sqrt{5}}$$

Calculate the perimeter and the hydraulic mean depth from the following relations

$P=B+D\sqrt{5}$

$R = A/P=(BD+D^2/2)/(B+D\sqrt{5})$

Calculate the actual mean velocity of low from Kutters equation or Mannings or Chezys formula. If this value of velocity is same as that found step 2, the assumed depth is correct. If not, repeat the calculations with a changed value of D till the two velocities are the same.

$$V=((23+(1/N)+(0.00155/S))/(1+(23+(0.00155/S))(N/\sqrt{R})))(\sqrt{[RS]})$$

Type 2: Q, N, m and B/D

Calculate A in terms of D

$B/D = x \quad B = Dx$

$A = BD + (D^2/2) \quad = xD^2+(D^2/2) \quad A = D^2(x+0.5)$

2) The value of velocity V is known in terms of D by

Kennedy's equation

$V=0.55mD^{0.64}$

Substitute the values of V and An in the continuity equation and solve for D. thus

$Q = A X V = D^2(x+0.5) X 0.55mD^{0.64}$

$Q= 0.55m(x+0.5) D^{2.64}$

Hence $D = (Q/(0.55m(x+0.5)))^{(1/2.64)}$

in the above relation Q, m and x are known. Hence D is determined

3) Knowing D, calculate B and R from the following relations

$B = xD$

and $R = (BD + D^2/2)/(B+D\sqrt{5})$

4) Calculate the velocity V from Kennedy's equation

$V = 0.55\ m\ D^{0.64}$

5) Knowing V and R, determine the slope S from Kutter's flow equation. The equation can be solved trial and error.

6)

LACEYS THEORY

True Regime:

Artificial channel having a certain fixed section and a certain fixed slope can behave regime only , if the following conditions are satisfied:

- Discharge is constant
- Flow is uniform
- Silt charge is constant (i.e, The amount of silt is constant)
- Silt grade is constant (i.e, the type and size of silt is always the same)
- Channel is flowing through the material which can be scoured as easily as it can be deposited. (incoherent alluvium) .
  - Artificial channel can never be in true regime

INITIAL REGIME:

- Only bed slope will varies due to dropping of silt, and its cross section and wetted perimeter remains unaffected, even then then the channel can exhibit no silting and no scouring properties.
- When water flows through an excavated channel with somewhat narrower dimensions and defective slopes , the silt carried by the water may get dropped in the upper reaches , thereby increasing the channel bed slope and velocity.
- The increased velocity leads to a non – silting equilibrium is called as initial regime.
- The rigidity of the channel bank provides working stability. (Controls velocity, slopes and cross section)

FINAL REGIME:

No resistance from the sides , and all the variables such as perimeter, depth , slope are equally free to vary and finally get adjusted according to discharge and silt grade, then the channel is said to have achieved permanent stability, called final regime.

The section of will be like,

Semi-ellipse - greater the width of the water surface (coarse silt)

Semi – circle - fine silt

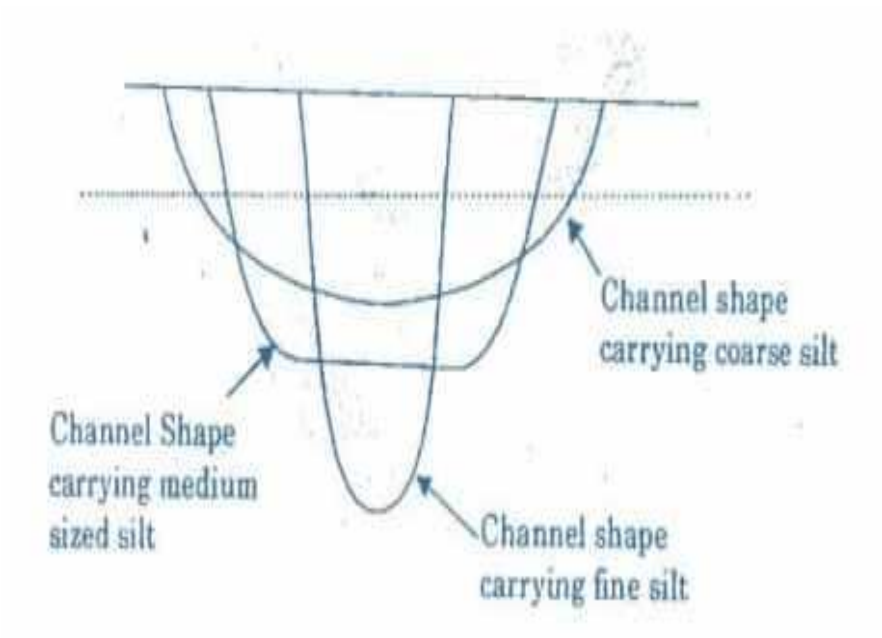

Figure 14: Channel Shape

Comparision of kennady and Lacys theorem

1. Kennady considered a trapezoidal channel section, hence he neglected the eddies generated from the sides . The eddies has only horizontal component and it does not have silt supporting power. For this reason kennadys velocity formula is bases in depth of flow (y). But, lacy consider a cup shapes section (semi elliptical) and that the entire wetted perimeter (P) of the channel contributes to the generation of silt supporting eddies

2. Kennady stated all the channel to be in the state of regime provided they did not silt or scour. But, Lacey differentiated two regime conditions (Initial regime and final regime).

3. More importance to silt factor

4. The Kutters rugosity coefficient is a guess work . But Lacey produced general regime flow equation.

5. Laceys established a relationship between width and depth of the channel (P,A).

6. Lacey fixed regime slope.

LACEY'S REGIME THEORY

Channel Design Procedure

1.Q, Mean dia of silt particles m_r or silt factor f should be known

- **Calculate the silt factor f** $= 1.76 \sqrt{d_{mm}}$
- **Find out velocity V** $= (Qf^2/140)^{1/6}$

Where, Q is in cumecs

V is in m/s

f- silt factor, d_{mm} = Average particle size in mm

2. Work out the hydraulic mean depth (R) from the equation

$$R = \frac{5}{2}\ (V2/f)$$

3. Compute area of channel section A = Q/V

4. Compute wetted perimeter, P = $4.75\sqrt{Q}$

5. Slope , S = $[\frac{f5/3}{3340\ Q\ 1/6}]$.

SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – IV – IRRIGATION ENGINEERING – SCI1401

DIVERSION HEADWORKS

Introduction

The works, which are constructed at the head of the canal, in order to divert the river water towards the canal, so as to ensure a regulated continuous supply of silt-free water with a certain minimum head into the canal, are known as diversion heads works.

Objective of Diversion Head Works

- ✓ To rise the water level at the head of the canal.
- ✓ To form a storage by constructing dykes (embankments) on both the banks of the river so that water is available throughout the year
- ✓ To control the entry of silt into the canal and to control the deposition of silt at the head of the canal To control the fluctuation of water level in the river during different seasons.

Selection of Site for Diversion Head Works

- At the site, the river should be straight and narrow
- The river banks should be well defined.
- The valuable land should not be submerged when the weir or barrage is constructed.
- The elevation of the site should be much higher than the area to be irrigated.
- The site should be easily accessible by roads or railways.
- The materials of construction should be available in vicinity of the site.
- The site should not be far away from the command area of the project, to avoid transmission loss.

Storage structure : Usually a dam, which acts like a reservoir for storing excess runoff of a river during periods of high flows and releasing it according to a regulated schedule.

Diversion structure: which may be a weir or a barrage that raises the water level of the river slightly, not for creating storage, but for allowing the water to get diverted through a canal situated at one or either of its banks? The diverted water passed through the canal may be used for irrigation, industry, domestic water needs or power generation.

Diversion Structures:

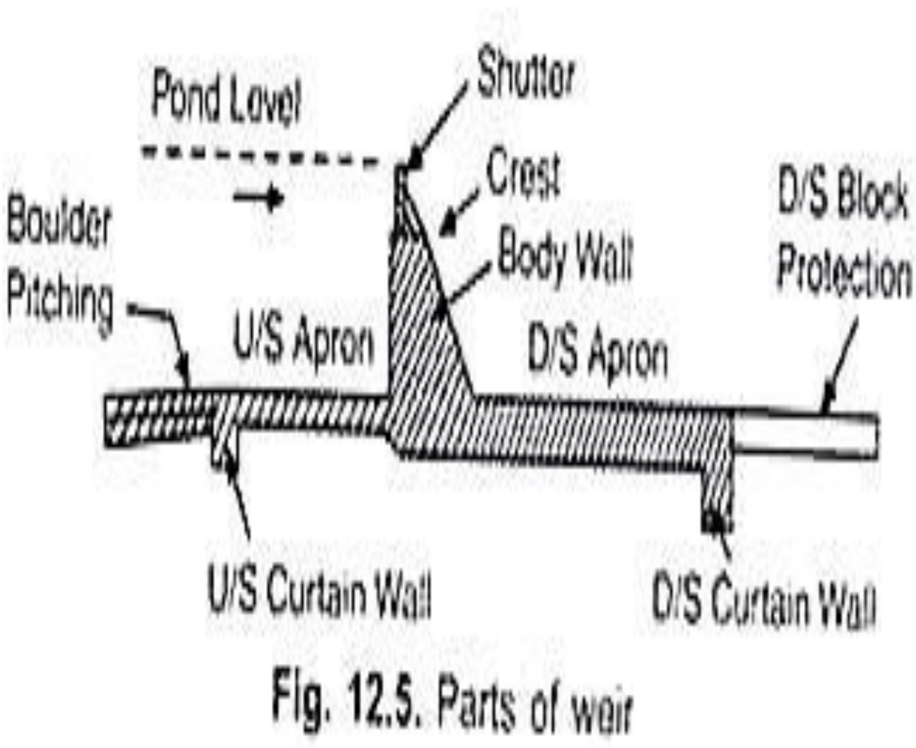

Figure 1: Parts of Weir

Layout of a Diversion Head Works and its components

A typical layout of a canal head-works is shown in figure below. *Such a head-works consists of*:

- Weir proper
- Under-sluices
- Divide wall
- River Training works
- Fish Ladder
- Canal Head Regulator
- River Training Works e.g. Guide bank, Marginal bunds, spur and groyne etc.
- Shutters and Gates
- Silt Regulation Works

Weir and Barrage

It is a barrier constructed across the river to raise the water level on the upstream side of the obstruction in order to feed the main canal.

The ponding of water can be achieved either only by a raised crest across the river or by a raised crest supplemented by gates or shutters, working over the crest.

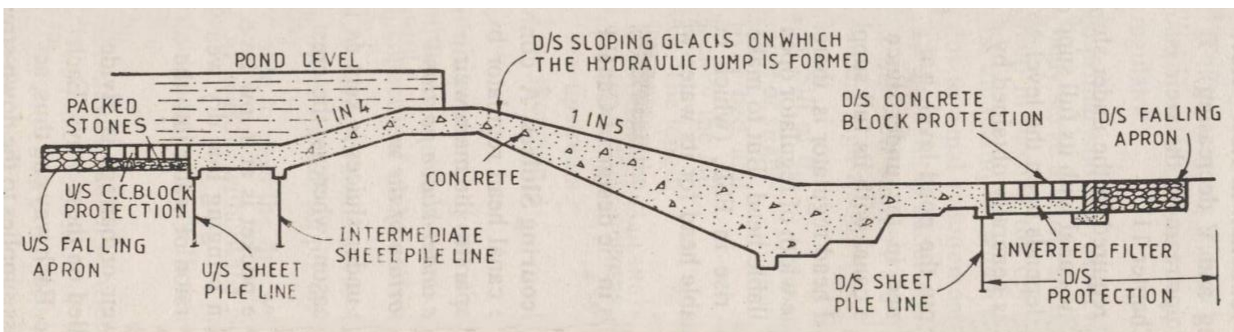

Figure 2: A typical cross-section of a modern concrete weir

Definition:

Weir

If the major part or the entire ponding of water is achieved by a raised crest and a smaller part or nil part of it is achieved by the shutters, and then this barrier is known as a ***weir***.

1. A solid obstruction put across river to raise its water level and divert water into canal (low head structure)
2. Vertical drop wall or crest wall
3. Upstream, downstream cut off wall at the ends of impervious floor
4. Launching apron for prevention of scour
5. Graduated inverted filter on downstream surface floor end to relieve the uplift pressure

Gravity and Non-gravity weirs:

When the weight of the weir (i.e. its body and floor) balances the uplift pressure caused by the head of the water seeping below the weir, it is called a gravity weir.

On the other hand, if the weir floor is designed continuous with the divide piers as reinforced structure, such that the weight of concrete slab together with the weight of divide piers keep the structure safe against the uplift then the structure may be called as a non-gravity weir.

In the latter case, RCC is to be used in place of brick piers Considerable savings may be obtained, as the weight of the floor can be much less than what is required in gravity weir.

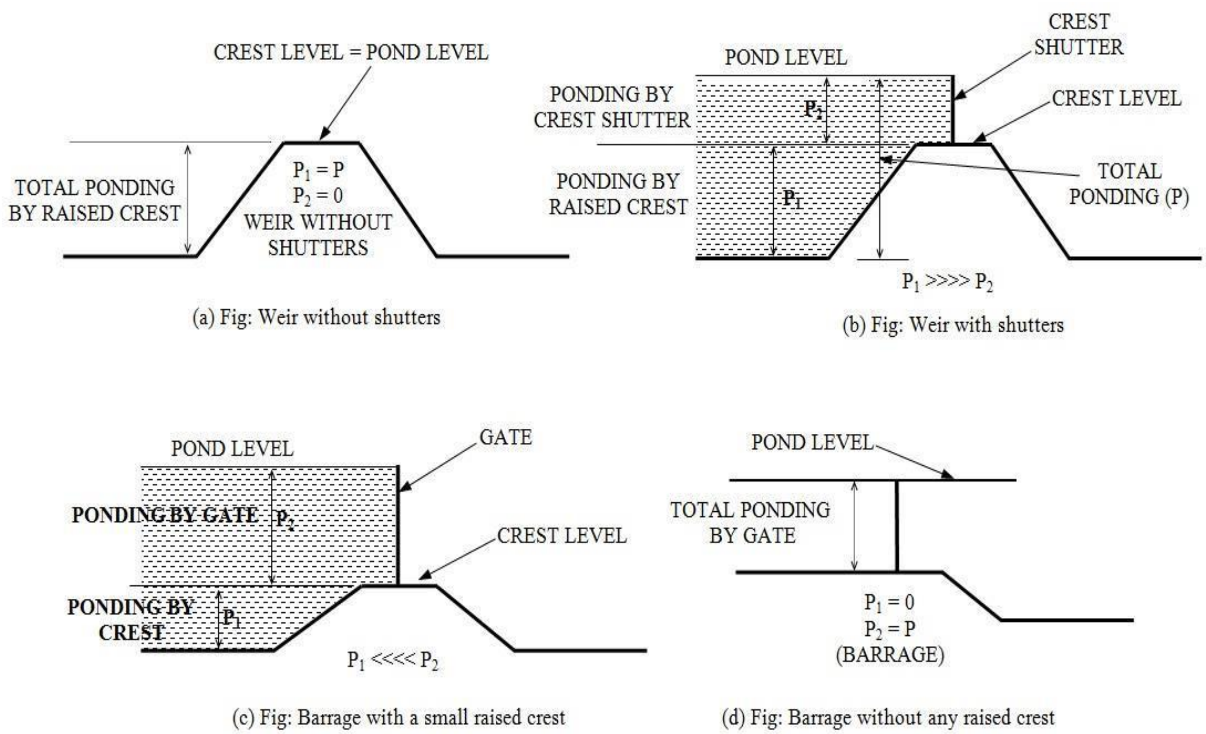

Figure 2: Weirs and Barrages

Types of weirs

(a) Masonry weirs with vertical drop

(b) Rock-fill weirs with sloping aprons

(c) Concrete weirs with sloping glacis

Masonry weirs with vertical drop

Masonry weir wall is constructed over the impervious floor. Cut-off walls are provided at both ends of the floor. Sheet piles are provided below the cut off walls. The crest shutters are provided to raise the water level, if required. The shutters are dropped down during flood. The masonry weir wall may be vertical on both face and sloping on both face and vertical on downstream face and sloping in upstream face.

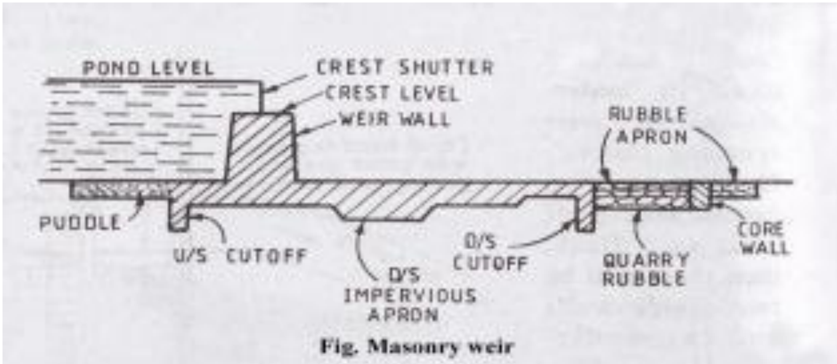

Figure 3: Masonry weir

Rock-fill weirs with sloping aprons

It consists of masonry breast wall which is provided with adjustable crest shutter. The upstream rock-fill portion is constructed with boulders forming a slope of 1 in 4. The boulders are grouted with cement mortar. The downstream sloping apron consists of core walls. The intermediate spaces between the core walls are filled up with boulders maintaining a slope of 1 in 20. The boulders are grouted properly with cement mortar.

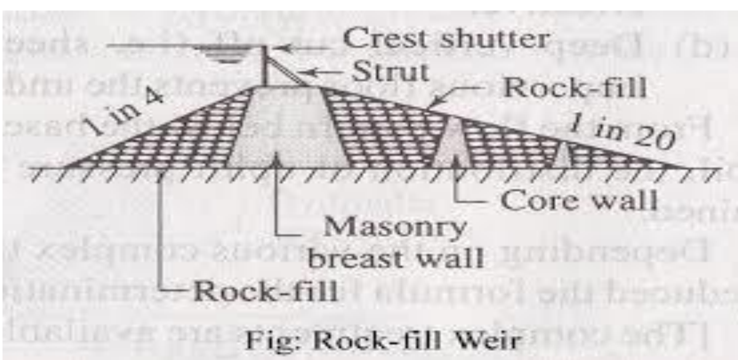

Figure 4: Rock –fill weir

Concrete weir

Now-a-days, the weir is constructed with reinforced cement concrete. The impervious floor and the weir are made monolithic. The cut off walls are provided at the upstream and downstream end of the floor and at the toe of the weir. Sheet piles are provided below the cut-off walls. The crest shutters are also provided which have dropped down during the flood.

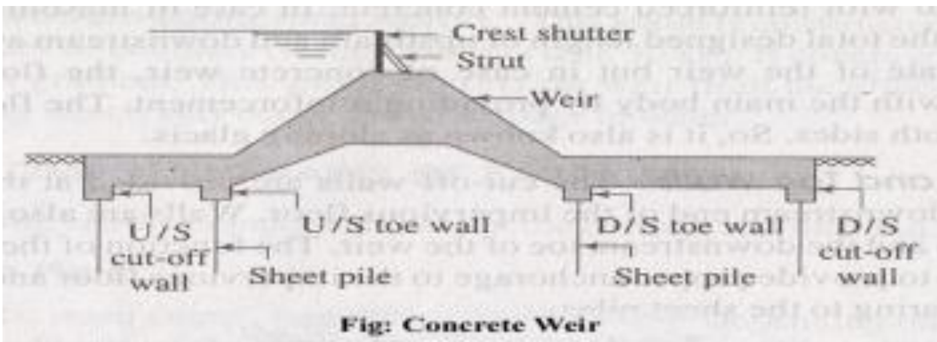

Figure 5: Concrete Weir

Location of Weirs

A weir should be

- ✓ The river where the river is unlikely to change its course.
- ✓ The weir has to be built high enough to fulfil command requirements. During high floods, the river could overtop its embankments and change its course. Therefore, a location with firm, well defined banks should be selected for the construction of the weir.
- ✓ Where possible, the site should have good bed conditions, such as rock outcrops.

Barrage

If most of the ponding is done by gates and a smaller or nil part of it is done by the raised crest, then the barrier is known as a barrage or a river regulator.

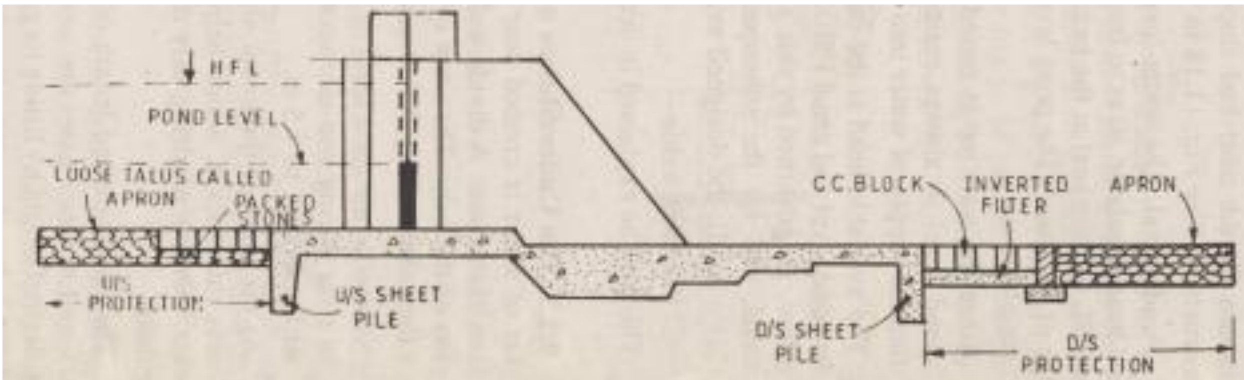

Figure 6 : A typical cross-section of a barrage

Afflux:

- ✓ The rise in the highest flood level (HFL) upstream of the weir due to construction of the weir across the river is called.
- ✓ In case of weir, the afflux caused during high floods is quite high. But in case of a barrage, the gates can be opened during high floods and the afflux will be nil or minimum.

Choice between a weir and a barrage

- ✓ The choice between a weir and a barrage is largely governed by cost and convenience in working.
- ✓ A shuttered weir will be relatively cheaper but will lack the effective control possible in the case of a barrage.
- ✓ A barrage type construction can be easily supplemented with a roadway across the river at a small additional cost. Barrages are almost invariably constructed now-a-days on all important rivers.

Table :1 Difference Between Weir and Barrage

Difference between Barrage and Weir SL	**Barrage**	**Weir**
(a)	Low set crest	High set crest
(b)	Ponding is done by means of gates	Ponding is done against the raised crest or partly against crest and partly by shutters
(c)	Gated over entire length	Shutters in part length
(d)	Gates are of greater height	Shutters are of smaller height, 2 m
(e)	Gates are raised clear off the high floods to pass floods	Shutters are dropped to pass floods
(f)	Perfect control on river flow	No control of river in low floods
(g)	Gates convenient to operate	Operation of shutters is slow, involve labour and time
(h)	High floods can be passed with minimum afflux	Excessive afflux in high floods
(i)	Less silting upstream due to low set crest	Raised crest causes silting upstream
(j)	Longer construction period	Shorter construction period
(k)	Silt removal is done through under sluices	No means for silt disposal
(l)	Road and/or rail bridge can be constructed at low cost	Not possible to provide road-rail bridge
(m)	Costly structure	Relatively cheaper structur

Layout of a Diversion Head Works and its components

A typical layout of a canal head-works is shown in figure below. *Such a head-works consists of*:

- ✓ Weir proper
- ✓ Under-sluices
- ✓ Divide wal
- ✓ River Training works
- ✓ Fish Ladder
- ✓ Canal Head Regulator
- ✓ River Training Works e.g. Guide bank, Marginal bunds, spur and groyne etc.
- ✓ Shutters and Gates
- ✓ Silt Regulation Works

1. **Weir Proper:**

   It is a barrier constructed across the river. It aims to raise the water level in order to feed the canal.

2. **Under-sluices:**

   The under sluices are the openings provided at the base of the weir or barrage. These openings are provided with adjustable gates. Normally, the gates are kept closed. The crest of the under-under sluice portion of the weir is kept at a lower level (1 1.5 m) than the crest of the normal portion of the weir. The suspended silt goes on depositing in front of the canal head regulator. When the silt deposition becomes appreciable the gates are opened and the deposited silt is loosened with an agitator mounting on a boat. The muddy water flows towards the downstream through the scouring sluices. The gates are then closed. But, at the period of flood, the gates are kept opened.

The main functions of under-sluices are:

- ✓ To maintain a well defined deep channel approaching the canal head regulator.
- ✓ To ensure easy diversion of water into the canal through the canal head regulator even during low flow.
- ✓ To control the entry of silt into the canal
- ✓ To help scouring and of the silt deposited over the under-sluice floor and removing towards the downstream side.
- ✓ To help passing the low floods without dropping the shutters of the weir

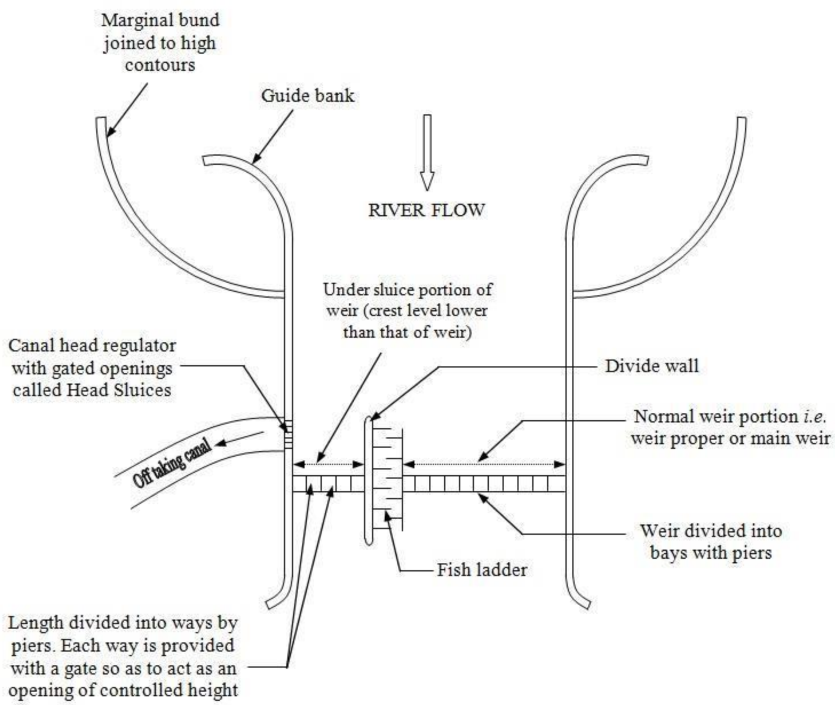

Fig: Typical layout of diversion head-works

Figure 9: Diversion Head works

Divide Wall

The divide wall is masonry concrete wall constructed at right angle through the axis of the weir.The divide wall extends on the upstream side beyond the beginning of the canal head regulator; and on the downstream side, it extends up to the end of the loose protection of the under-sluices.

The divide wall is a long wall constructed at right angles in the weir or barrage; it may be constructed with stone masonry or cement concrete. On the upstream side, the wall is extended just to cover the canal head regulator and on the downstream side, it is extended up to the launching apron.

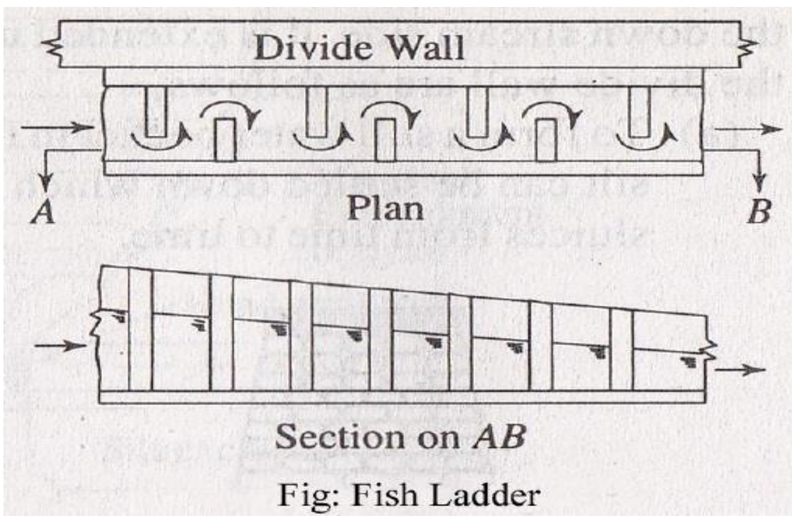

Figure 10: Fish Ladder

The main functions of the divide walls:

It separates the ‘under-sluices’ with lower crest level from the ‘weir proper’ with higher crest level.

It helps in providing a comparatively less turbulent pocket near the canal head regulator, resulting in deposition of silt in this pocket and, thus, to help in the entry of silt-free water into the canal.

It helps to keep cross-current, if any, away from the weir.

Fish Ladder

It is device by which the flow energy can be dissipated in such a manner as to provide smooth flow at sufficiently low velocity, not exceeding 3 to 3.5 m/s.

A narrow opening including suitable baffles or staggering devices in it is provided adjacent to the divide wall.

The fish ladder is provided just by the side of the divide wall for the free movement of fishes. Rivers are important source of fishes.

There are various types of fish in the river. The nature of the fish varies from type to type. But in general, the tendency of fish is to move from upstream to downstream in winters and from downstream to upstream in monsoons. This movement is essential for their survival. Due to construction of weir or barrage, this movement gets obstructed, and is detrimental to the fishes. In the fish ladder, the fabe walls are constructed in a zigzag manner so the velocity of flow the ladder does not exceed 3 m/s. The width, length and height of the fish ladder depends on the nature and the type of the weir or barrage.

Canal Head Regulator or Head sluices

A structure which is constructed at the head of the canal to regulate flow of water is known as canal head regulator. It consists of a number of piers which divide the total width of the canal into a number of spans which are known as bays. The piers consist of number tiers on which the adjustable gates are placed. The gates are operated form the top by suitable mechanical device. A platform is provided on the top of the piers for the facility of operating the gates. Again some piers are constructed on the downstream side of the canal head to support the roadway.

Functions of Canal Head Regulator:

- It regulates the supply of water entering the canal
- It controls the entry of silt in the canal
- It prevents the river-floods from entering the canal

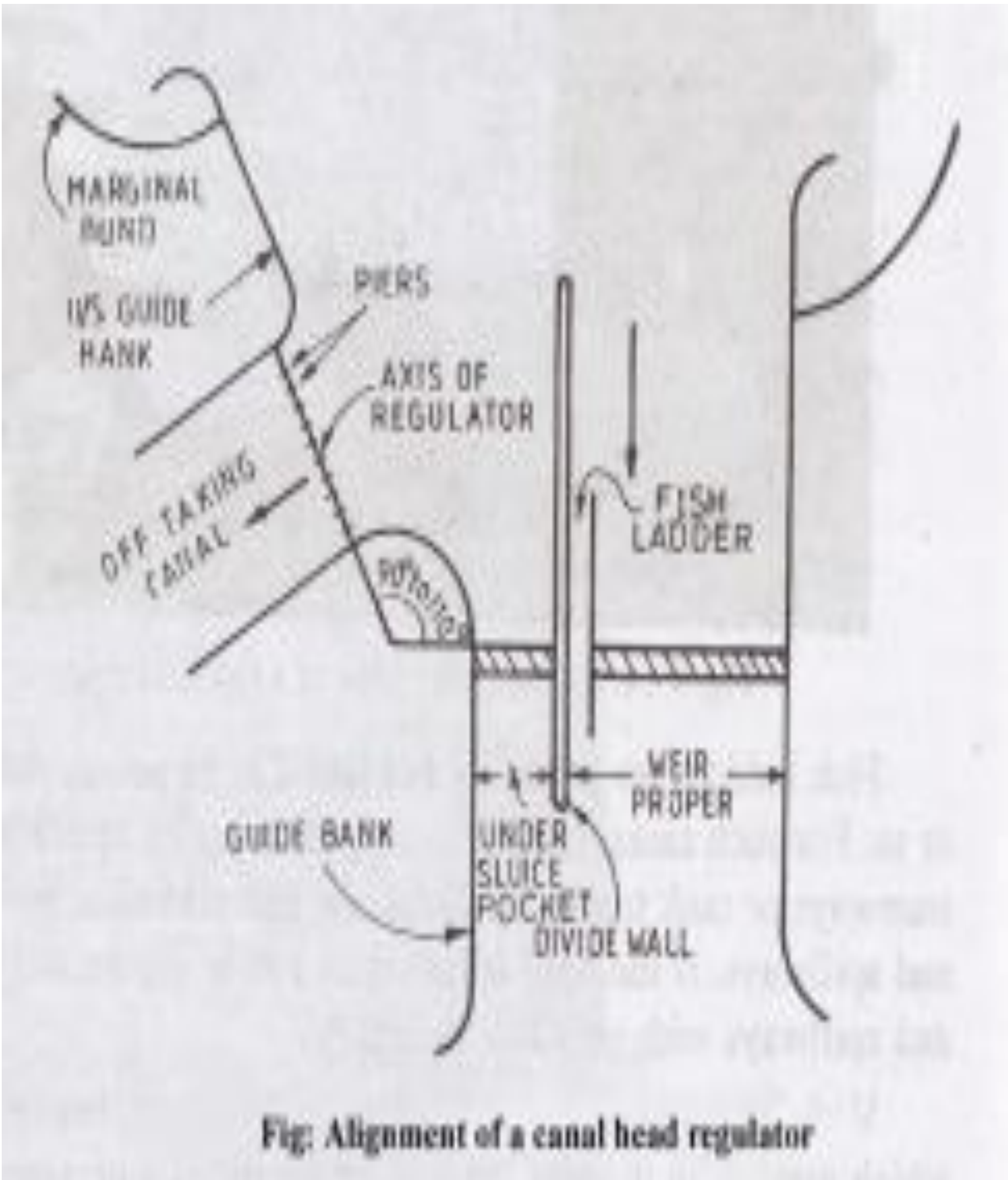

Figure 11: Alignment of canal head regulator

The water from the under-sluice pocket is made to enter the regulator bays, so as to pass the full supply discharge into the canal. The maximum height of these gated openings, called head sluices will be equal to the difference of Pond Level and Crest Level of the regulator.

- The entry of silt into the canal is controlled by keeping the crest of the head regulator by about 1.2 to 1.5 meters higher than the crest of the under-sluices.
- If a silt-excluder is provided, the regulator crest is further raised by about 0.6 to 0.7 meter.
- Silt gets deposited in the pocket, and only the clear water enters the regulator bays.
- The deposited silt can be easily scoured out periodically, and removed through the under-sluice openings.

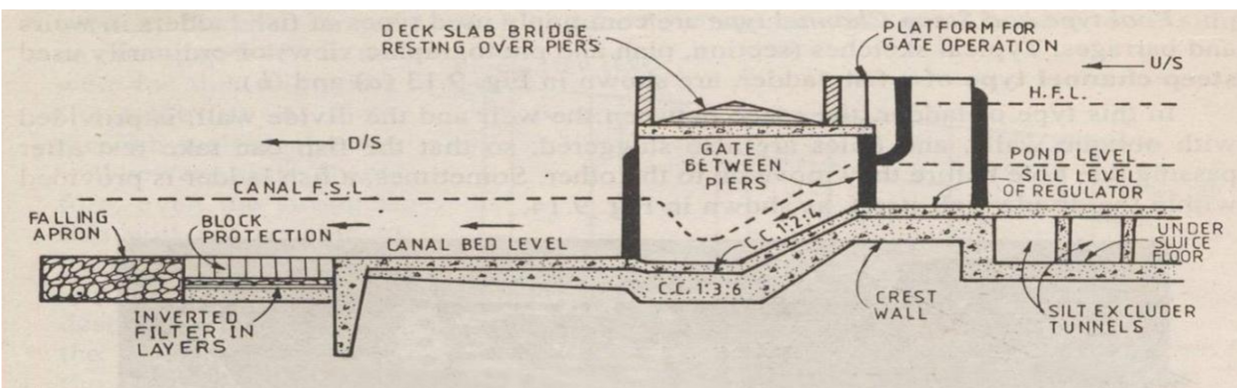

Figure 12: A typical section through a Canal Head Regulator (CHR)

River Training Works

River training works are required near the weir site in order to ensure a smooth and an axial flow of water, and thus, to prevent the river from outflanking the works due to a change in its course.

The river training works required on a canal headwork are:

(a) Guide banks
(b) Marginal bunds
(c) Spurs or groynes

(a) Guide Bank

When a barrage is constructed across a river which flows through the alluvial soil, the guide banks must be constructed on both the approaches to protect the structure from erosion.

Guide bank serves the following purposes:

- It protects the barrage from the effect of scouring and erosion
- It provides a straight approach towards the barrage
- It controls the tendency of changing the course of the river.
- It controls the velocity of flow near the structure

(b) Marginal Bunds

The marginal bunds are earthen embankments which are constructed parallel to the river bank on one or both the banks according to the condition. The top width is generally 3 m to 4 m. The side slope on the river side is generally 1.5: 1 and that on the country side is 2:1.

The marginal bunds serve the following purposes:

- It prevents the flood water or storage water from entering the surrounding area which
- May be submerged or may be water logged.
- It retains the flood water or storage water within a specified section.
- It protects the towns and villages from devastation during the heavy flood.
- It protects valuable agricultural lands.

(c) Groynes

Groyns are impervious permanent structures constructed on the curve of a river to protect the river bank from erosion. They extend from the bank towards the bed by making an angle of 60o to 75o with the bank. The angle may be towards the upstream or downstream. Sometimes, it is made perpendicular to the river bank. These are constructed with rubble masonry in trapezoidal section and the surface is finished with stone pitching or concrete blocks.

- The stone pitching or the concrete blocks are set with rich cement mortar.
- The length of the groyne depends on the width and nature of the river.
- The top width varies from 3 m to 4 m. The side slope may be 1½: 1 or 2:1.
- The groynes are provided in series throughout the affected length of the river bank.
- The spacing between the adjacent groynes is generally kept as $2L$, where L is the length of the groyne.
- These are recommended for the river where the permanent solution of erosion control is extremely necessary.

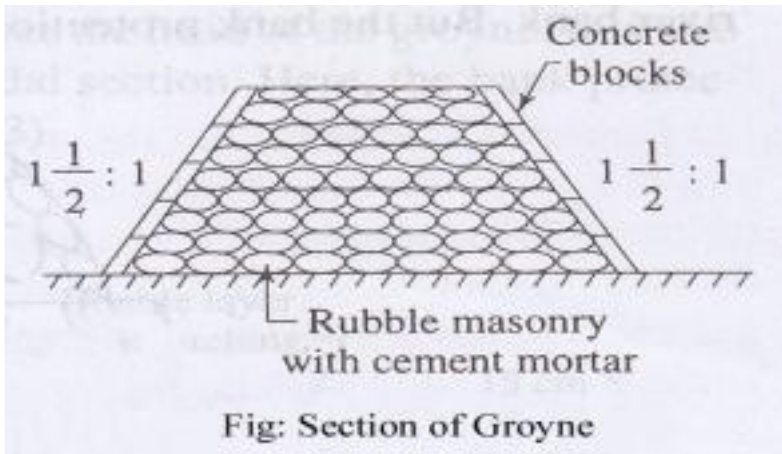

Figure 13: Section of Groyne

The groynes may be designated as follows:

(a) **Attracting Groyne:** The groyne which is constructed obliquely to the bank by making an angle of 60 to 75o towards the downstream is known as attracting groyne, here the flow of water is attracted towards the bank, and the velocity of flow is reduced to such a extent that it can not cause any erosion to the bank. However, a bank protected of stone pitching is provided for safety.

(b) **Repelling Groyne:** A groyne which is aligned towards upstream at an angle of 60o to 75o with the river bank is known as repelling groyne. A still water pocket is formed on the upstream where silting takes place. Here, the bank protection is not necessary, because the flow of water does not touch the bank and there is no effect of erosion on the bank. But still boulder pitching should be provided for safety.

(c) **Deflecting Groyne:** The groyne which is constructed perpendicular to the river bank is known as deflecting groyne. Here the flow of water is deflected from bank by the perpendicular obstruction i.e. groyne. The flow of water follows an undulating path just outside the head of the groyne. An eddy current is formed on the upstream side of the groyne. This eddy current will not affect the river bank. But the bank protection is provided for safety.

(d)

Shutters and Gates:

Functions of shutters and gates are:

They maintain pond level.

They raise water level during low flow.

Pond Level

The water level required in the under-sluice pocket upstream of the Canal Head Regulator, so as to feed the canal with its full supply, is known as Pond Level.

The FSL of the canal at the head depends upon the level of the irrigated areas and the slope of the canal.

Pond Level = Canal FSL + 1.0 to 1.2 m

Silt Regulation works

The entry of silt into a canal, which takes off from a head works, can be reduced by constructed certain special works, called silt control works.

These works may be classified into the following two types:

(a) Silt Excluders

(b) Silt Ejectors

(a) Silt Excluders

Silt excluders are those works which are constructed on the bed of the river, upstream of the head regulator. The clearer water enters the head regulator and silted water enters the silt excluder. In this type of works, the silt is, therefore,, removed from the water before in enters the canal

(b) Silt Ejectors

Silt ejectors, also called silt extractors, are those devices which extract the silt from the canal water after the silted water has traveled a certain distance in the off-take canal. These works are, therefore, constructed on the bed of the canal, and little distance downstream from the head regulator.

Water logging

Definition:

When the conditions are so created that the crop root-zone gets deprived of proper aeration due to the presence of excessive moisture or water content, the tract is said to be waterlogged. To create such conditions it is not always necessary that under groundwater table should enter the crop root-zone. Sometimes even if water table is below the root-zone depth the capillary water zone may extend in the root-zone depth and makes the air circulation impossible by filling the pores in the soil.

The water logging may be defined as rendering the soil unproductive and infertile due to excessive moisture and creation of anaerobic conditions. The phenomenon of water logging can be best understood with the help of a hydrologic equation, which states that

Inflow = Outflow -I- Storage

Here inflow represents that amount of water which enters the subsoil in various processes. It includes seepage from the canals, infiltration of rainwater, percolation from irrigated fields and subsoil flow. Thus although it is loss or us, it represents the amount of water flowing into the soil.

The term outflow represents mainly evaporation from soil, transpiration from plants and underground drainage of the tract. The term storage represents the change in the groundwater reservoir.

Causes of Water logging:

After studying the phenomenon of water logging in the light of hydrologic equation main factors which help in raising the water-table may be recognized correctly.

They are:

i. Inadequate drainage of over-land run-off increases the rate of percolation and in turn helps in raising the water table.

ii. The water from rivers may infiltrate into the soil.

iii. Seepage of water from earthen canals also adds significant quantity of water to the underground reservoir continuously.

iv. Sometimes subsoil does not permit free flow of subsoil water which may accentuate the process of raising the water table.

v. Irrigation water is used to flood the fields. If it is used in excess it may help appreciably in raising the water table. Good drainage facility is very essential.

Effects of Water logging:

The water logging affects the land in various ways. The various after effects are the following:

1. Creation of Anaerobic Condition in the Crop Root-Zone:

When the aeration of the soil is satisfactory bacteriological activities produce the required nitrates from the nitrogenous compounds present in the soil. It helps the crop growth. Excessive moisture content creates anaerobic condition in the soil. The plant roots do not get the required nourishing food or nutrients. As a result crop growth is badly affected.

2. Growth of Water Loving Wild Plants:

When the soil is waterlogged water loving wild plant life grows abundantly. The growth of wild plants totally prevents the growth of useful crops.

3. Impossibility of Tillage Operations:

Waterlogged fields cannot be tilled properly. The reason is that the soil contains excessive moisture content and it does not give proper tilts.

4. Accumulation of Harmful Salts:

The upward water movement brings the toxic salts in the crop root-zone. Excess accumulation of these salts may turn the soil alkaline. It may hamper the crop growth.

5. Lowering of Soil Temperature:

The presence of excessive moisture content lowers the temperature of the soil. In low temperature the bacteriological activities are retarded which affects the crop growth badly.

6. Reduction in Time of Maturity:

Untimely maturity of the crops is the characteristic of waterlogged lands. Due to this shortening of crop period the crop yield is reduced considerably.

CANAL FALLS

Irrigation canals are constructed with some permissible bed slopes so that there is no silting or scouring in the canal bed. But it is not always possible to run the canal at the desired bed slope throughout the alignment due to the fluctuating nature of the country slope.

Generally, the slope of the natural ground surface is not uniform throughout the alignment. Sometimes, the ground surface may be steep and sometimes it ma be very irregular with abrupt change of grade. In such cases, a vertical drop is provided to step down the canal bed and then it is continued with permissible slope until another step down is necessary. This is done to avoid unnecessary huge earth work in filling. Such vertical drops are known as ***canal falls or simply falls***.

Necessity / Importance of Canal Falls:

When the slope of the ground suddenly changes to steeper slope, the permissible bed slope can not be maintained. It requires excessive earthwork in filling to maintain the slope. In such a case falls are provided to avoid excessive earth work in filling when the slope of the ground is more or less uniform and the slope is greater than the permissible bed slope of canal.

Types of Canal Falls - Classification of fall

The following are the different types of canal falls that may be adopted according to the site condition:

Ogee fall

In this type of fall, an ogee curve (a combination of convex curve and concave curve) is provided for carrying the canal water from higher level to lower level. This fall is recommended when the natural ground surface suddenly changes to a steeper slope along the alignment of the canal.

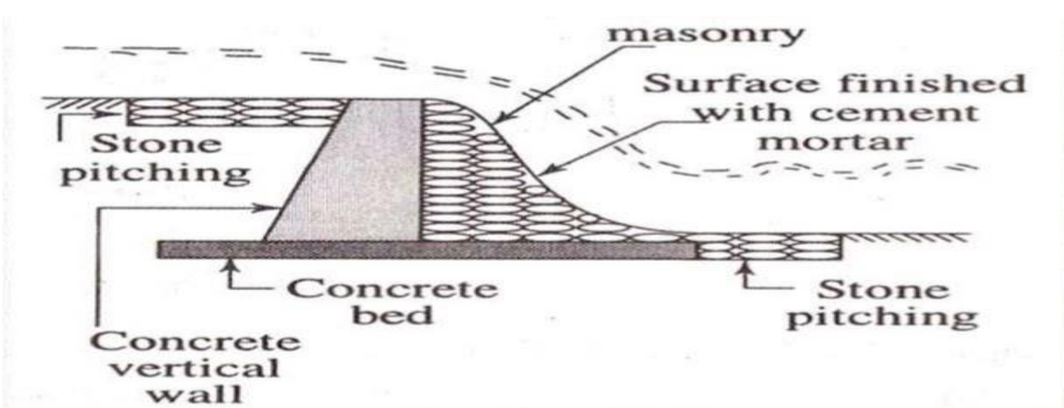

Figure 14: Ogee fall

- ✓ The fall consists of a concrete vertical wall and concrete bed.
- ✓ Over the concrete bed the rubble masonry is provided in the shape of ogee curve.
- ✓ The surface of the masonry is finished with rich cement mortar (1:3).
- ✓ The upstream and downstream side of the fall is protected by stone pitching with cement grouting.
- ✓ The design consideration of the ogee fall depends on the site condition.

Rapid fall

The rapid fall is suitable when the slope of the natural ground surface is even and long. It consists of a long sloping glacis with longitudinal slope which varies from 1 in 10 to 1 in 20.

- Curtain walls are provided on the upstream and downstream side of the sloping glacis.
- The sloping bed is provided with rubble masonry.
- The upstream and downstream side of the fall is also protected by rubble masonry.
- The masonry surface is finished with rich cement mortar (1: 3).

Stepped fall

Stepped fall consists of a series of vertical drops in the form of steps. This fall is suitable in places where the sloping ground is very long and requires long glacis to connect the higher bed level with lower bed level.

- This fall is practically a modification of the rapid fall.
- The sloping glacis is divided into a number of drops so that the flowing water may not cause any damage to the canal bed. Brick walls are provided at each of the drops.
- The bed of the canal within the fall is protected by rubble masonry with surface finishing by rich cement mortar (1:3).

Trapezoidal Notch Fall

In this type of fall a body wall is constructed across the canal. The body wall consists of several trapezoidal notches between the side piers and the intermediate pier or piers. The sills of the notches are kept at the upstream bed level of the canal.

SPILL WAY

Spillway: The spillways are openings provided at the body of the dam to discharge safely the excess water or flood water when the water level rises above the normal pool level
Definition: Spillways are structures constructed to provide safe release of flood waters from a dam to a downstream are, normally the river on which the dam has been constructed.
Necessity of Spillways

- The height of the dam is always fixed according to the maximum reservoir capacity. The normal pool level indicates the maximum capacity of the reservoir. The water is never stored in the reservoir above this level. The dam may fail by over turning so, for the safety of the dam the spillways are essential.

- The top of the dam is generally utilized by making road. The surplus water is not be allowed to over top the dam, so to stop the over topping by the surplus water, the spillways become extremely essential.

- To protect the downstream base and floor of the dam from the effect of scouring and erosion, the spillways are provided so that the excess water flows smoothly.

Location of Spillway Generally, the spillways are provided at the following places

- Spillways may be provided within the body of the dam.
- Spillways may sometimes be provided at one side or both sides of the dam.
- Sometimes by-pass spillway is provided which is completely separate from the dam.

Determination of discharge capacity and number of spillways

The maximum discharge capacity and the number of spillways are determined by studying the following factors:

(a) By studying the flood hydrograph of past ten years, the maximum flood discharge may be computed which is to be disposed off completely through the spillways.

(b) The water level in the reservoir should never be allowed to rise above the maximum pool level and should remain in normal pool level. So, the volume of water collected between maximum pool level and minimum pool level computed, which indicates the discharge capacity of spillways.

(c) The maximum flood discharge may also be computed from other investigation like, rainfall records, flood routing, empirical flood discharge formulae, etc.

(d) From the above factors the highest flood discharge is ascertained to fix the discharge capacity of spillways.

(e) The natural calamities are beyond the grip of human being. So, an allowance of about 25 % should be given to the computed highest flood discharge which is to be disposed off.

(f) The size and number of spillways are designed according to the design discharge.

Types of Spillways - Classification of Spillways

There are different types of spillways that can be provided depending on the suitability of site and other parameters. Generally a spillway consists of a control structure, a conveyance channel and a terminal structure, but the former two may be combined in the same for certain types. The more common types are briefly described below.

The common types of spillway in use are the following:

1. Free Overfall (Straight Drop) Spillway
2. Overflow (Ogee) Spillway
3. Chute (Open Channel/Trough) Spillway
4. Side Channel Spillway
5. Shaft (Drop Inlet/Morning Glory) spillway
6. Tunnel (Conduit) spillway
7. Siphon spillway

The water flowing down from the spillways possess a large amount of kinetic energy that is generated by virtue of its losing the potential head from the reservoir level to the level of the river on the downstream of the spillway. If this energy is not reduced, there are dangers of scour to the riverbed which may threaten the stability of the dam or the neighboring river valley slopes. The various arrangements for suppressing or killing of the high energy water at the downstream toe of the spillways are called **Energy Dissipaters**.

(a) Drop Spillway

In drop spillway, the over flowing water falls freely and almost vertically on the downstream side of the hydraulic structure. This type of spillway is suitable for weirs or low dams. The crest of the spillway is provided with nose so that the water jet may not strike the downstream base of the structure. To protect the structure from the effect of scouring horizontal impervious apron should be provided on the downstream side. Sometimes a basin is constructed on the downstream side to form a small artificial pool which is known as water cushion. This cushion serves the purpose of energy dissipater

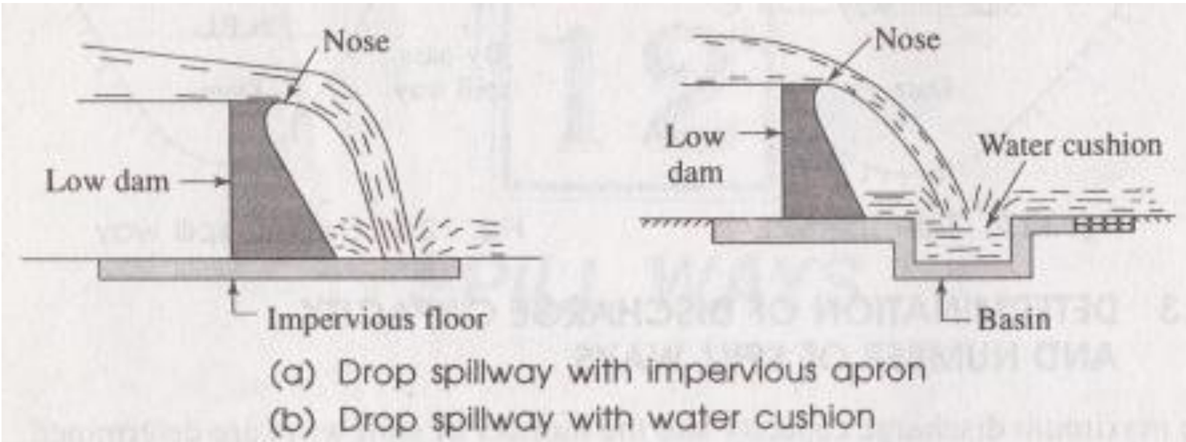

Figure 15: Drop spillway

(c) Ogee Spillways

The ogee spillway is a modified form of drop spillway. Here, the downstream profile of the spillway is made to coincide with the shape of the lower nappe of the free falling waterjet from a sharp crested weir. In this case, the shape of the lower nappe is similar to a projectile and hence downstream surface of the ogee spillway will follow the parabolic path where "0" is the origin of the parabola. The downstream face of the spillway forms a concave curve from a point "*T*" and meets with the downstream floor. This point "*T*" is known as point of tangency. Thus the spillway takes the shape of the letter "*S*" (i.e. elongated form). Hence, this spillway is termed as ogee spillway.

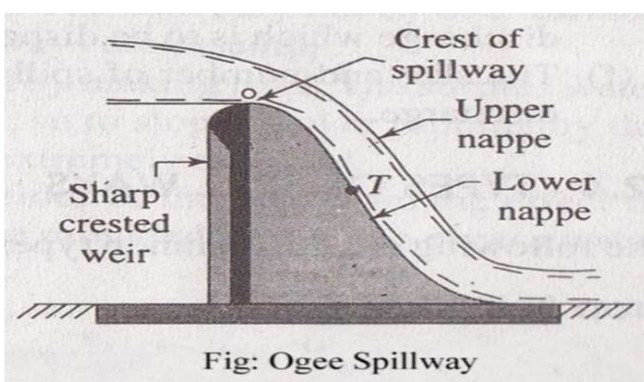

Figure 16: Ogee Spillway

The shape of the lower nappe is not same for all the head of water above the crest of the weir. It differs with the head of water. But for the design of the ogee spillway the maximum head is considered. If the spillway runs with the maximum head, then the overflowing water just follows the curved profile of the spillway and there is no gap between the water and the spillway surface and the discharge is maximum.

Chute (Trough) Spillway

In this type of spillway, the water, after flowing over a short crest or other kind of control structure, is carried by an open channel (called the "chute" or "trough") to the downstream side of the river. The control structure is generally normal to the conveyance channel. The channel is constructed in excavation with stable side slopes and invariably lined. The flow through the channel is super-critical. The spillway can be provided close to the dam or at a suitable saddle away from the dam where site conditions permit.

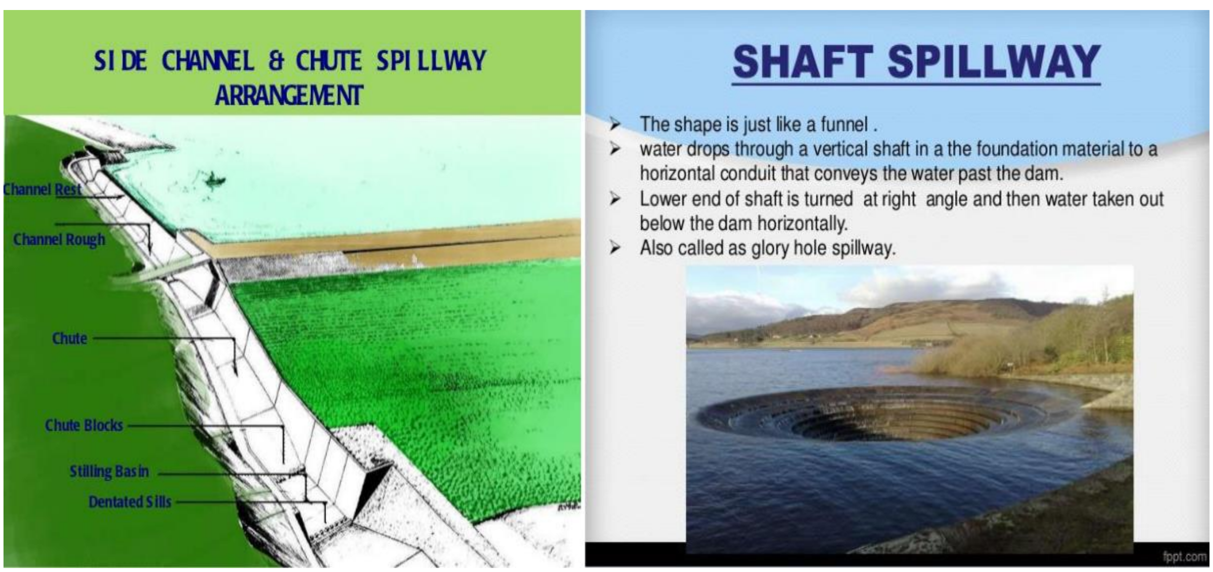

Figure 17: Spillway

Side Channel Spillway

Side channel spillways are located just upstream and to the side of the dam. The water after flowing over a crest enters a side channel which is nearly parallel to the crest. This is then carried by a chute to the downstream side. Sometimes a tunnel may be used instead of a chute.

Shaft (Morning Glory or Glory hole) Spillway

This type of spillway utilizes a crest circular in plan, the flow over which is carried by a vertical or sloping tunnel on to a horizontal tunnel nearly at the stream bed level and eventually to the downstream side. The diversion tunnels constructed during the dam construction can be used as the horizontal conduit in many cases.

Siphon Spillway

As the name indicates, this spillway works on the principle of a siphon. A hood provided over a conventional spillway forms a conduit. With the rise in reservoir level water starts flowing over the crest as in an "ogee" spillway. The flowing water however, entrains air and once all the air in the crest area is removed, siphon action starts. Under this condition, the discharge takes place at a much larger head. The spillway thus has a larger discharging capacity. The inlet end of the hood is generally kept below the reservoir level to prevent floating debris from entering the conduit. This may cause the reservoir to be drawn down below the normal level before the siphon action breaks and therefore arrangement for de-priming the siphon at the normal reservoir level is provided.

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – V – IRRIGATION ENGINERING – SCI1401

IRRIGATION WATER MANGEMENT

Irrigation Scheduling Concept

Irrigation scheduling is essential for good water management and it deals with two classical questions related to irrigation.

(1) how much to irrigate and

(2) How often to irrigate.

How often and how to irrigate is function of irrigation water needs of the crop.

For example, if irrigation water need of crop is 5 mm/day, each day crop needs a water layer of 5 mm over the whole cropped area. However, 5 mm of water need not be supplied every day. Generally, drips irrigation systems are designed to meet irrigation water requirement on daily or at an interval of 2-3 day days. However, longer gap between irrigations is maintained in other irrigation system. In any case, irrigation interval is chosen such that crop does not suffers from water stress.

In many cases irrigation scheduling is performed based on the irrigator's personal experience, plant appearance, watching the neighbour, or just simply irrigating whenever water is available.However, over the year a number of irrigation scheduling techniques based on soil water monitoring, plant monitoring and water balance approach have been developed.

Advantages of Irrigation Scheduling

1. It enables the farmer to schedule water rotation among the various fields to minimize crop water stress and maximize yields.
2. It reduces the farmer's cost of water and labour as it minimizes the number of irrigations.
3. It lowers fertilizer costs by holding surface runoff and deep percolation (leaching) to a minimum.
4. It increases net returns by increasing crop yields and crop quality.
5. .It minimizes water-logging problems by reducing the drainage requirements.
6. It assists in controlling root zone salinity problems through controlled leaching.
7. It results in additional returns by using the "saved" water to irrigate non-cash crops

that otherwise would not be irrigated during water-stress periods.

Full Irrigation

It provides the enough water to meet the entire irrigation requirement and is aimed at achieving the maximum production potential of the crop. Excess irrigation may reduce crop yield because of decreased soil aeration.

Deficit Irrigation

It means partially meeting the crop water requirement. It is practiced when there is water scarcity or the irrigation system capacity is limited. With deficit irrigation root zone is not filled to the field capacity moisture level.

Deficit irrigation is justified in case where reducing water application below full irrigation causes production cost to decrease faster than revenue decline due to reduced yield. This method allows plant stress during one or more periods of growing season. However, adequate water is applied during the critical growth stages to maximize water use efficiency.

Irrigation Interval

It is the number of days between two successive irrigations. It depends on the crop ET, effective rainfall, and available water holding capacity of the soil in the crop root zone and management allowable depletion.

Methods of Irrigation scheduling

1. Soil indicators
2. Climatological
3. Plant indices
4. Water balance

Soil Indicator

There are number of methods based on soil indicators. These include feel and appearance, soil moisture monitoring using gravimetric method, neutron probe, TDR, or soil moisture tension measurement using tensiometer, porous block etc.

In these methods, the available soil water held between field capacity and permanent wilting point in the effective crop root zone depth is taken as guide for determining practical irrigation schedules.

Alternatively soil moisture tension is also used as a guide for timing irrigations. Feel and appearance is one of the oldest and simple methods of determining the soil moisture content. It is done by visual observation and feel of the soil by hand. The accuracy of judgment improves with experience.

Climatological Approach (IW: CPE Ratio)

Irrigation scheduling on the basis of ratio betweenthe depth of irrigation water (IW) and cumulative evaporation from U.S.W.B. Class A panevaporimeter minus the precipitation since the previous irrigation (CPE) proposed by Prihar et al. (1974).

The accuracy of the method depends on proper installation of pan evaporimeter and raingauge and the measurements of pan evaporation and rainfall. Further, suitability of the method is site specific and limited to particular variety of crop. An IW/CPE ratio of 1.0 indicates irrigating the crop with water equal to that lost in evaporation from the evaporimeter.

Plant Indices Approach

The plants readily respond to the deficit in soil water. Some of the indices used to schedule irrigation based on this response are discussed below:

Visual Plant Symptoms

The visual signs of plants are used as an index for scheduling irritations. These include colour of plants, curling and rolling of leaves, wilting of leaves, change in leaf angle etc. Plant water stress in maize and beans crop is reflected through rolling of leaves in case of maize and change in angle of leaves in case of bean .Successful interpretation of crop stress requires keen observation and experience. Secondly sometimes symptoms may be misleading and by the time they appear it may be too late to irrigate.

Figure 1: Rolling of leaves in maize and change of leaf angle in beans.

Plant Water Potential

Plant water potential is a measure of the energy status of plant water and is analogous to the energy measurements of soil water. This serves as a better index of physiological and bio-chemical phenomena occurring in the plant. Plant or leaf water potential can be precisely measured either by a Pressure bomb or pressure chamber apparatus are generally used for in situ measurement of leaf water potential, whereas the dye method is used in the laboratory.

The critical plant water potential varies with crop. When potential values falls below critical limits specific to crop and growth stage, physiological and growth factors are adversely affected and thus they can serves as a guideline for irrigation scheduling. In case of cotton critical potential ranges from 1.2 to 1.25 MPa throughout the crop life.

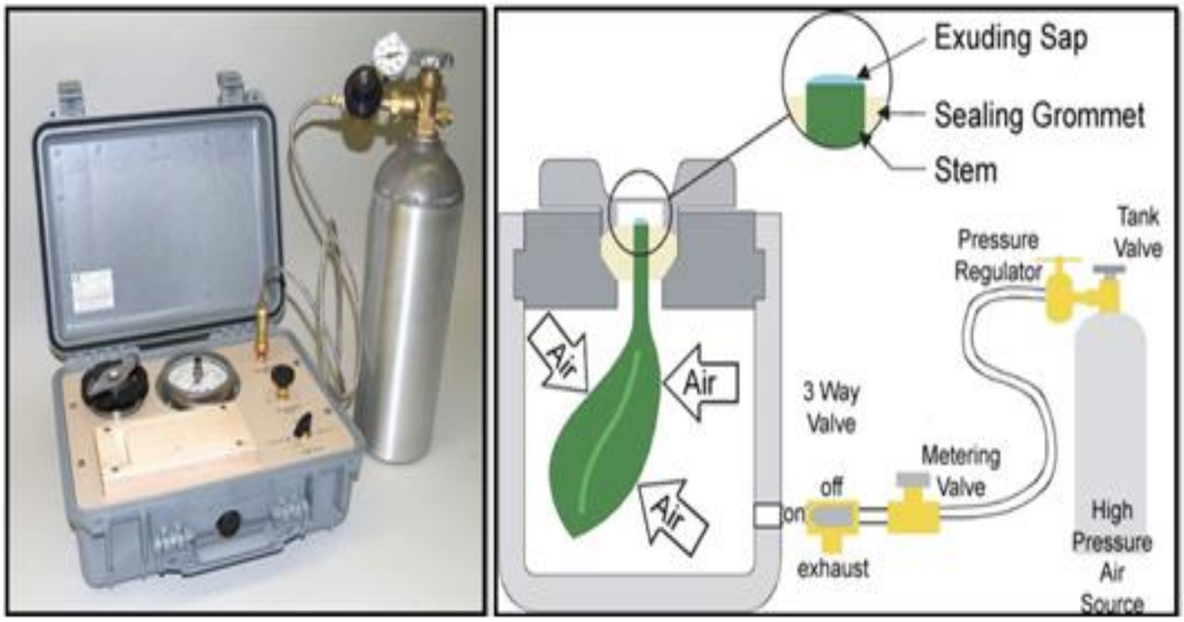


Figure 2 :Pressure chamber apparatus

Canopy Temperature

The canopy temperature reflects the internal water balance of the plant, and can be used as a potential indicator for scheduling irrigation to crops. It can be measured by porometer, infrared thermometer .The leaf canopy temperature is sensitive index in crops like soyabean, oats, barley, wheat, sorghum and maize.

Water Balance Approach

Irrigation scheduling based on water balance approach uses readily available information on weather, crop and soil information. The soil water balance can be expressed in terms of soil moisture depletion as follows:

$$SMD_i = SMD_{i-1} + ET_{c,i} + DP_i - I_i - P_{e,i} + GW_i$$

SMD= total soil moisture depletion in the root zone and is defined as the difference between total soil moisture stored in the root zone at the field capacity and the currentmoisture status;

ET_c = crop evapotranspiration;

DP = deep percolation;

I = irrigation amount;

P_e= effective rainfall;

GW = the capillary rise/ground water contribution and i = time index.

PARTICIPATORY IRRIGATION

Introduction:

Participatory Approach is crucial for management of irrigation projects for conserving and optimal utilization of resources.

Participatory Irrigation Management (PIM) refers to involvement of irrigation users in all aspects of Irrigation Management and at all levels

Water Users' Association (WUA) has been registered for the purpose in various states in India.

Definition of Water Users Association

A Water Users Association (WUA) is a co-operative association of individual water users who wish to undertake

water-related activities for their mutual benefit

The specific nature of the service that a WUA provides will differ from case to case

Because member needs will differ from one area to another, a WUA is normally established in response to the aspirations of its members.

Scope of WUAs

An efficient and equitable supply and distribution ofwater ensuring optimum utilization for improvement of agricultural production.

Scientific and systematic development and maintenance of irrigation infrastructure.

Management and maintenance of the irrigation system for effective and reliable supply and distribution of water.

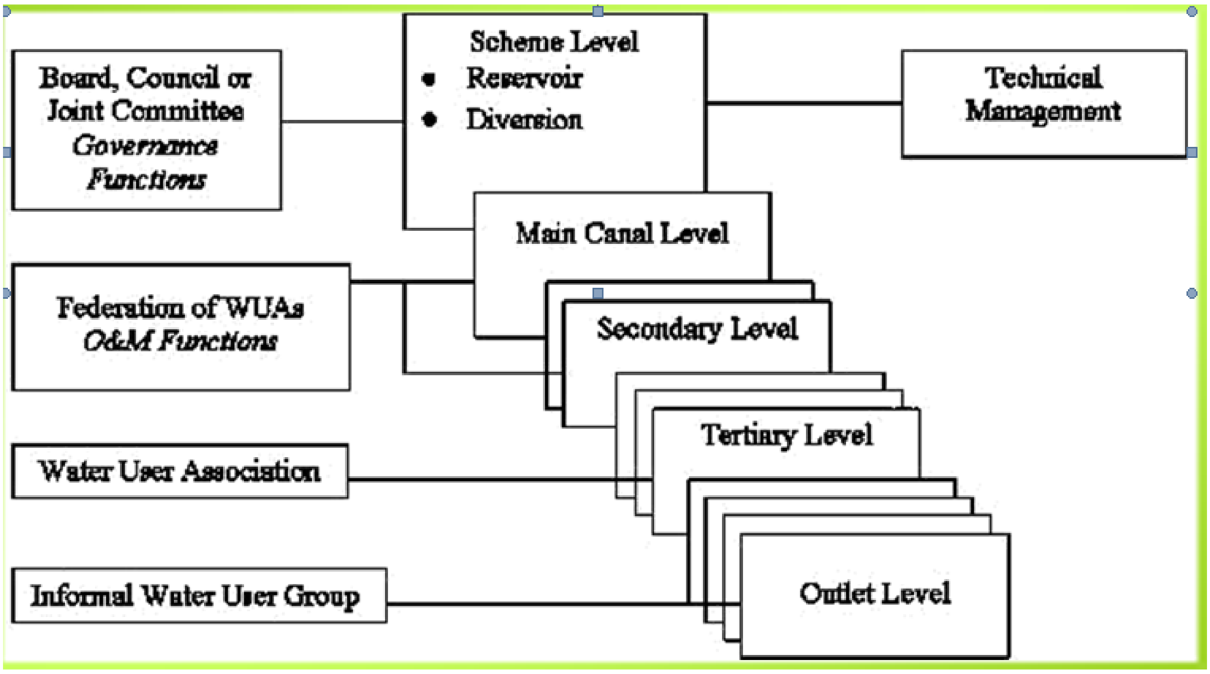
Play coordinative role in recovery of irrigation water rates from the beneficiary farmers.

The protection of the environment and ecological balance.

Scale of Operation of WUAs

WUAs differ enormously from one another in their geographical scale of operation. One reason for this is that they are often federated upward in up to three tiers, each of which covers an area of operation of an entirely different order and performs substantially different functions for its members or member organizations.

Multi-tiered User Organization of a Surface Irrigation Scheme



Functions of WUAs: Core functions

1. Acting as an interface between the farmers and the main system management .
2. Water distribution.
3. Operation and maintenance of the irrigation and drainage system.
4. Collection (and assessment) of water charges and other user charges or special charges that the WUAs may levy.
5. Resolution of local disputes amongst members.
6. Conflict resolution between members and non-members
7. Drainage
8. Provision of drinking water from canals
9. Design and construction of new works as well as rehabilitation of canals and structures.
10. Maintenance of commercial, financial and water accounting records
11. Cooperating with other WUAs to form federations of WUAs to take over larger canal sub-systems.

The additional and optional tasks could be as follows:

1. Recommending of cropping patterns and package of agricultural practices suitable for the WUA's farmers.
2. Helping to arrange for other inputs, to members for undertaking irrigated agriculture.
3. Irrigation extension and propagation of better on-farm water application and better intra-outlet command water management.
4. Agriculture extension and farmers training.
5. Encouraging and taking up of conjunctive water use, including community lift irrigation.
6. Post harvest practices (Grading, Packaging, Storage and Marketing)
7. Any other task as mutually agreed upon by the members.

Election to the WUA's

In a WUA, all water users are its members. The Act provides with voting rights, to those members who have been registered as owners or tenants in the record or rights. Where both the owner and the tenant are landholders of the same land, the rights are given to the tenant.

The WUA has a Managing Committee, which attends to the day-to-day functioning.This body has a President and Managing Committee members ranging from 4 to 10, who are elected by the members.

Resolving disputes

The Managing Committee of the distributory committee determines a dispute arising between a member and the Managing Committee of the Water Users Association or between two or more Water Users Associations.

The Apex Committee whose decision shall be final shall determine a dispute between a member and the Managing Committee of a Project Committee.

State Government Role in Participatory Irrigation Management

- ✓ The State Government has to create an enabling environment through policy resolutions, specific programs, projects and activities to be implemented or sponsored by the government,
- ✓ Providing intellectual, administrative and implementational leadership,
- ✓ Putting into place legal and administrative provisions and procedures,
- ✓ Undertaking mass awareness building and promotional efforts,
- ✓ Pproviding technical advice and technical back up, as well as funds, to WUAs for selective activities,
- ✓ Ensuring attitudinal and behavioral change amongst employees of all government departments directly or indirectly concerned with Tank, Canal (and Community Lift) irrigation,
- ✓ Creating nodal points of PIM in all concerned government departments both at the Central Government and State Government levels.
- ✓ Preparing guidelines and field manuals
- ✓ Arranging for various sorts of PIM related training

Helping WUAs to rehabilitate old irrigation systems to bring them up to at least a minimum operational level.

Involving NGOs and Community Organizers.

Providing incentives, monetary, or otherwise for (i) farmers to undertake PIM, and (ii) government staff to facilitate it((p) helping WUAs in conflict resolution with other agencies

Gendered Issues in WUAs

- ✓ Rules for membership in Water Users Groups are problematic as patriarchy and male dominance. The concept of water user is deeply ingrained in Indian culture as the one who owns the land.
- ✓ Although women have legal rights to inherit, and own land, the practice is different.
- ✓ Women particularly, landless are not perceived as water users and therefore not perceived as eligible as members of water users associations.

Policy Issues in WUAs

- ✓ It is clear from the above that the provision of secure access to water is an important tool with which poverty can be alleviated, although its effectiveness depends on secure access to other productive resources such as land and training and capacity building.

- ✓ It should be kept in mind that WUAs institutions are a set of rules. These includes the official rules and procedures as well as unofficial values, norms, traditions and practices. These together determine how authority and power are distributed among the membership. Changing official rules alone does not lead to actual change unless associated practices are also changed.